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Factors Affecting Fruit Setting I. Stayman Winesap

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FACTORS AFFECTING FRUIT SETTING. I.

STAYMAN WINESAP

FREEMAN S. HOWLETT

Fruit setting studies have previously been undertaken in regard to apple varieties in general, but it has become evident that the varieties differ markedly in their fruit setting characteristics. Because of this fact, studies of separate varieties have been undertaken. This bulletin is the first of a series on apple varieties of commercial importance in Ohio.

Stayman Winesap and the other members of the Winesap family are less dependable in producing full commercial yields than are a number of other varieties, such as Rome, Jonathan, and Wealthy. Such variation in fruitfulness involves capricious fruit setting rather than failure of fruit bud formation. This study purposes to determine and to analyze those factors which, in the main, account for this peculiar fruit setting habit. The relationship of these factors to commercial orchard practices is also considered, and suggestions are advanced which will aid in a more uniform and productive yield.

Stayman Winesap, according to its originator, Dr. J. Stayman (44), was a selected seedling from Winesap seed planted in 1866 at Leavenworth, Kansas. The tree first fruited in 1875. For a number of years the variety was little planted, but by 1900 it was becoming established in commercial orchards. At present it is a leading commercial variety in a number of fruit regions in this country; while in Ohio it ranks fourth in importance among fall and winter varieties.

LITERATURE REVIEW

The first investigation to determine the degree of self fruitfulness, as well as the effective cross-pollinizing varieties, of Stayman Winesap was that of Powell (39) in Delaware. The trees used were 8 years old and the flowers were emasculated. He obtained no fruits from selfing or from crossing with York Imperial. He attributed the drop of flowers which reached the size of peas to excessive vigor of the trees. He also reported that in several young, well-cared-for orchards the variety was setting lightly. Close (5) continued Powell's work using Ben Davis, Early Ripe, Williams, and Yellow Transparent as pollinizers of Stayman. He obtained fruit only from Yellow Transparent (1.2 per cent). These flowers were also emasculated. Ballard (2) pollinized emasculated Stayman flowers with the following varieties, obtaining the percentage sets given: Bonum, 6; Delicious, 6; Early Ripe, 2.3; Grimes, 1.6; Nickajack, 13.1; and Williams, 14.2.

Vincent (45) reported 0.5 per cent set from selfed Stayman flowers; whereas Crandall (7) obtained no fruits. Morris (33) obtained 2 per cent set from emasculated Stayman flowers pollinated by McIntosh, but no fruit resulted from the use of Wealthy as the pollinizer.

Auchter (1) reported the per cent sets given in Table 1 with emasculated Stayman flowers. Much higher percentage sets were obtained with open-pollinated flowers of Wealthy, Grimes Golden, Yellow Transparent, Gano, and York Imperial than with open-pollinated Stayman flowers.

TABLE 1.—Set of Fruit on Stayman Winesap Produced by Various Pollinizers
Maryland [After Auchter (1)]

Pollen parent	Flowers pollinated		Flowers setting fruit	
	1919	1920	1919	1920
	Number	*Number*	*Percentage*	*Percentage*
Stayman Winesap	....	560	....	0.0
Grimes Golden	558	231	2.8	0.0
Rome Beauty	539	239	10.4	0.0
York Imperial	472	246	3.2	0.4
Open-pollinated	1000	1190	10.0	4.0
Open-pollinated	....	904	....	5.3

In similar experiments Dorsey (14) used dwarf trees grown in pots in a greenhouse. The results given in Table 2 are from those crosses in which at least 50 emasculated flowers were cross pollinated.

TABLE 2.—Set of Fruit on Stayman Winesap Produced by Various Pollinizers
Minnesota [After Dorsey (14)]

Pollen parent	Tree number	Flowers setting fruit		
		1918	1919	1920
		Percentage	*Percentage*	*Percentage*
Oldenburg	22	9.8	22.4	....
Oldenburg	26	1.2	....	....
Oldenburg	28	....	18.2	....
Oldenburg	121	....	....	17.8
Oldenburg	62	....	....	3.0
King David	33	2.0	....	....
Hibernal	26	....	....	0.0
Okabena	26	....	8.2	....
Patten Greening	62	....	....	0.0

It was surprising to find such small sets from flowers under temperature conditions favorable for fruit setting. In general, Dorsey found a considerable proportion of the seeds in these crosses aborted. He suggested that this abortion might be due to both "nutrition and genetic combination."

The highest percentage sets from selfed Stayman flowers up to this time were reported by Vinson (46). The terminal flower only was emasculated and pollinated. The results given in Table 3 were taken before the second drop.

TABLE 3.—Set of Fruit on Stayman Winesap Produced by Various Pollinizers
Ohio [From Ann. Rept. Ohio Agr. Exp. Sta. (46)]

Pollen parent	Flowers pollinated	Flowers setting fruit
	Number	*Percentage*
Stayman Winesap	235	0.0
Delicious	231	5.6
Ensee	154	20.1
Grimes Golden	136	17.6
Jonathan	224	11.2
McIntosh	129	19.3
Rome Beauty	136	43.3
Wealthy	146	0.6
Yellow Transparent	128	51.6
York Imperial	61	60.6

Vinson also reported experiments in which Stayman trees were enclosed by cheesecloth frames with Jonathan and Delicious, respectively. After the June drop, 3.1 per cent of the flowers on the tree enclosed with Jonathan remained; whereas 3.9 of those on the tree enclosed with Delicious had set fruit.

In the pollination tests in Ohio reported by Howlett (27), small glassine bags were used to enclose partially deflorated clusters. The data are given in Table 4.

The pollen of all varieties was tested for germinability. The percentage sets, in general, were low and variable. On the other hand, the results with heavy-setting varieties, such as Baldwin, Grimes Golden, Jonathan, and Yellow Transparent, as the female parents showed high percentage sets. Although emasculation was probably more detrimental to Stayman than to these varieties, the young Stayman trees at Hambden set less than commercial crops, even though the flowers were not frost injured and provision for cross pollination had been made.

Cooper (6) in Arkansas reported no fruits from selfing Stayman, but 17.1 per cent from Yellow Transparent, 16.5 from Delicious, and 36.5 from Ben Davis as pollinizers. The clusters were partially deflorated and the flowers emasculated. Knowlton

(29) in his selfing and crossing experiments partially deflorated the clusters and emasculated the flowers. The data presented in Table 5 were taken before the June drop.

TABLE 4.—Set of Fruit on Stayman Winesap Produced by Various Pollinizers
Ohio [After Howlett (27)]

Pollen parent	Tree number and year	Flowers pollinated	Flowers setting fruit
Wooster			
		Number	*Percentage*
Stayman Winesap	374–1924	70	0.0
Grimes Golden		90	25.6
Jonathan		76	0.0
Open-pollinated		....	Tree yield 6.6 bu.
Delicious	374–1925	100	7.0
Jonathan		194	0.0
McIntosh		98	1.0
Open-pollinated		228	0.0*
Gallia Beauty	E–4–1925	94	6.3
Open-pollinated		....	Tree yield 3.2 bu.
McIntosh	E–3–1925	70	0.0
Open-pollinated		372	5.4
Hambden			
Grimes Golden	8–1924	182	4.9
Open-pollinated		113	2.6
Jonathan	10–1924	188	1.6
McIntosh		188	0.5
Open-pollinated		....	Below 8.0
Delicious	13–1924	152	7.1
Open-pollinated		....	Below 8.0
Yellow Transparent	30–1924	44	2.3
Open-pollinated		90	5.6

*Tree as a whole had a fair crop.

TABLE 5.—Set of Fruit on Stayman Winesap Produced by Various Pollinizers
West Virginia [After Knowlton (29)]

Pollen parent	Tree No.	Flowers pollinated	Flowers setting fruit
		Number	*Percentage*
Stayman Winesap	7	470	0.4
Delicious		533	17.0
Grimes Golden		437	10.0
Jonathan		524	3.4
Stayman Winesap	8	504	0.0
Delicious		600	17.1
Grimes Golden		417	10.5
Jonathan		507	5.3
Stayman Winesap	23	100	6.0
Ben Davis		307	30.0
Delicious		171	40.3
Grimes Golden		170	40.6
Stayman Winesap	15	371	5.7
Ben Davis		307	9.8
Delicious		408	10.8
Grimes Golden		218	18.8
Stayman Winesap	Hort. Farm	350	0.0
Grimes Golden		235	52.3
Jonathan		295	40.7

Luce and Morris (30) reported no fruits from selfing Stayman in Washington. Einset (15) in New York reported 27.0 per cent set from a few flowers of Stayman pollinated by McIntosh.

Summary of the literature review.—The data presented in the literature review show that Stayman Winesap as the female parent has given not only highly variable but also relatively low sets. The percentages obtained with the various pollinizers having highly germinable pollen have been, throughout the experiments, much lower than those obtained with such varieties as Jonathan, Grimes Golden, Wealthy, and Rome as the female parents. Furthermore, the same spread in percentage set occurred between the open-pollinated flowers of these varieties and those of Stayman. Because of partial defloration of clusters and the removal of petals and anthers only when emasculating the flowers, the percentages obtained in the more recent experiments are higher than those in the earlier work; yet they are still relatively low.

COMPETITION AMONG FLOWERS ON INDIVIDUAL CLUSTERS

Chemical studies by Howlett (26) have shown that during the rapid enlargement of flowers of Baldwin, Hubbardston, and Roxbury Russet up to full bloom, there is a marked increase on the absolute basis of total nitrogen, free reducing substances, total sugars, and insoluble carbohydrates in these organs. During this period, the leaves of the flower-bearing spurs also make rapid growth. In view of their own demands, it is unlikely that the leaves are able to supply a significant amount of newly synthesized food to the flowers. Thus, the development of the flowers must require, in addition to an adequate supply of water, a large amount of nitrogenous and carbohydrate materials, the greater proportion of which are drawn from the reserves in the older parts of the tree. The chemical analyses gave no indication as to whether the supply or the rate of translocation of these substances was sufficient to permit the development of flowers capable of setting fruit. It is to be recalled that during this period of rapid enlargement the processes occur within the ovules which lead to the development of a functional egg nucleus. It is possible that at this time the competition for growth-producing materials among the flowers of the individual clusters may be so severe as to occasion changes which prevent the flowers from setting fruit even when cross pollinated.

DEFLORATION EXPERIMENTS

In order to determine the effect of competition between flowers for food and water upon the set of fruit, comparison was made between partially deflorated and undeflorated clusters.

COMPETITION BETWEEN LATERALS DURING PERIOD OF RAPID ENLARGEMENT

Defloration of Stayman clusters in 1925.—The experiments in 1925 were undertaken to determine whether the competition between the enlarging lateral flowers of a cluster was sufficiently great to prevent certain ones from setting fruit. The index of the severity of the competition was the ability of the flowers to survive the first drop.

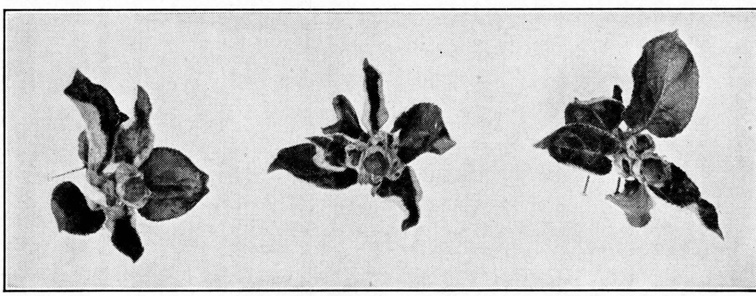

Fig. 1.—Stage of development of flowers at time of the first defloration, Tree 8-8. April 25, 1925

The procedure consisted in the partial defloration of clusters at two stages during the period from the opening of the fruit bud to full bloom. The first defloration was made when the clusters were scarcely opened sufficiently to permit separation and removal of flowers (Fig. 1). No attempt was made at the first defloration to select laterals other than the largest. The high temperatures from April 23 to 26 resulted in such rapid development that it was necessary to make the second defloration only one week later than the first, at a time when the lateral flowers were just exposing the anthers (Fig. 2).

Throughout the course of the experiments, the flowers left on the cluster bases, after partial defloration, were hand pollinated with pollen previously tested for germinability. The hand-pollinated flowers were emasculated in 1925 and 1926 by removing the petals, stamens, and, occasionally, the tips of the sepals (Fig. 5). In the subsequent experiments no emasculations were made.

The treatment and vigor of the trees used in the experiments are indicated in Table 6. The time of defloration of the clusters and the time of pollination of the flowers are given in Table 7.

In the first defloration of the vigorous trees, 8-8 and E-5, (Table 8) the results show that, as the number of lateral flowers left to a cluster was decreased, the percentage setting fruit increased. The increases in the set with each successive decrease in the number of flowers were not large.

Fig. 2.—Stage of flowers at time of hand pollination, April 27, 1925

The results of the second defloration were too irregular for interpretation. It was anticipated that severe competition during the period between the deflorations would be indicated by a decidedly smaller set of the flowers left at the second defloration than that of the corresponding number left at the first. But because of the small number of clusters deflorated such an interpretation from the data is unjustifiable.

On trees 8-8 and E-5, when the clusters were undeflorated, the percentage set of the terminal was higher than that of the laterals. On tree 8-8 it was higher, even when competing with four laterals, than the percentage set of one lateral alone. The difference in the percentage set between the hand-pollinated and the open-pollinated clusters was undoubtedly due to the effects of emasculation.

On the trees of low vigor, I-3 and H-2, only the terminal flowers of the hand-pollinated clusters set fruit. It is interesting to note that 94 per cent of the fruits resulting from open pollination on tree H-2, 71 per cent on tree I-3, and 78.7 per cent of those on tree E-5 were also terminal in position.

TABLE 6.—Cultural Treatment of Trees Used in the Fruit-setting Experiments—1925-1931

Tree No.	Years used	Year planted	Cultural system	Pruning	Fertilizer treatment	Growth
			Stayman Winesap			
8- 8	1925, 1926, 1930	1916	Sod	Moderate	5 lb. Am. Sul.	Vigorous
E- 5	1925	1916	Sod	Light	10 lb. Sod. Nit.	Vigorous
I- 3	1925	1916	Sod	None	None	Low vigor
H- 2	1925	1916	Sod	None	None	Low vigor
I- 2	1926	1916	Sod	None	None	Low vigor
149	1926, 1928, 1929	1916	Grass mulch	Moderate	5 lb. Sod. Nit.	Vigorous
637	1927, 1930	1917	Cultivation	Moderate	5 lb. Sod. Nit.	Vigorous
8-10	1927, 1930	1916	Sod	Moderate	5 lb. Sod. Nit.	Vigorous
8- 3	1927	1916	Sod	Moderate	5 lb. Sod. Nit.	Vigorous
616	1928	1918	Grass mulch	Moderate	5 lb. Sod. Nit.	Vigorous
622	1928	1920	Grass mulch	Moderate	5 lb. Sod. Nit.	Vigorous
147	1929	1916	Grass mulch	Heavy	5 lb. Sod. Nit.	Vigorous
8-11	1929	1916	Sod	Moderate	5 lb. Sod. Nit.	Mod. vigor
158	1929, 1931	1899	Grass mulch	Moderate	8 lb. Sod. Nit.	Vigorous
212	1930	1899	Grass mulch	Moderate	8 lb. Sod. Nit.	Vigorous
			Jonathan			
408- 7	1925	1900	Grass mulch	Moderate	5 lb. Sod. Nit.	Vigorous
408- 3	1925	1900	Grass mulch	Very light	None	Low to mod. vigor
408- 9	1926	1900	Grass mulch	Moderate	5 lb. Sod. Nit.	Vigorous

TABLE 7.—Time of Defloration, Time of Pollination, and Variety of Pollen Used in the Defloration Experiments—1925-1930

Tree number	Year	Time of defloration	Time of pollination		Pollen variety
			Terminal	Laterals	
		Stayman Winesap			
All trees	1925	1st, Apr. 21-22 2nd, Apr. 28-29	Apr. 28-29	Apr. 28-29	Grimes Golden
All trees	1926	May 4	May 15-17	May 15-17	Grimes Golden
All trees	1927	Apr. 21-22	May 7	May 7	Grimes Golden
149	1928	May 17	May 10	May 17	Grimes Golden
616, 622	1928	May 15	May 9	May 15	Grimes Golden
147, 149	1929	Apr. 24	Apr. 24	Apr. 26	Delicious
8-11	1929	Apr. 24	Apr. 27	Apr. 27	Delicious
212	1930	May 1	....	May 1	Jonathan
637	1930	May 2	....	May 2	Jonathan
8-8	1930	May 2	....	May 2	Jonathan
8-10	1930	May 2	....	May 2	Jonathan
		Jonathan			
408-7	1925	Apr. 23	Apr. 25	Apr. 25	Grimes Golden
408-3	1925	Apr. 23	Apr. 25	Apr. 25	Grimes Golden
408-9	1926	May 4	May 4	May 4	Grimes Golden

TABLE 8.—Effect of the Number and Position of Flowers in the Cluster Upon the Percentage Setting Fruit. Stayman Winesap—1925

Number and position of flowers	Clusters pollinated		Flowers setting fruit					
			Terminal		Laterals		Entire cluster	
	1st deflor.	2nd deflor.	1st deflor.	2nd deflor.	1st deflor.	2nd deflor.	1st deflor.	2nd deflor.
Tree 8-8								
	No.	*No.*	*Percentage*	*Percentage*	*Percentage*	*Percentage*	*Percentage*	*Percentage*
Open-pollinated clusters	121		....	....	....	....	11.7	
Terminal and 4 laterals	45	32	33.3	28.5	2.6	3.8	7.1	8.1
4 laterals	33	13	....	....	12.3	5.8	....	....
3 laterals	54	17	....	....	10.5	11.8	....	....
2 laterals	48	20	....	....	15.6	12.5	....	....
1 lateral	50	15	....	....	22.2	13.3	....	....
Tree E-5								
Open-pollinated clusters	233		....	....	....	....	9.7	
Terminal and 4 laterals	31	14	6.4	7.1	4.6	3.3	5.1	4.3
4 laterals	32	24	....	....	10.1	2.1	....	....
3 laterals	29	16	....	....	4.6	12.3	....	....
2 laterals	30	22	....	....	15.0	0.0	....	....
1 lateral	16	17	....	....	18.7	0.0	....	....
Tree I-3								
Open-pollinated clusters	36		....	....	....	....	0.0*	
Terminal and 4 laterals	28	20	7.1	0.0	0.8	0.0	2.1	0.0
4 laterals	32	37	....	....	0.0	0.0	....	....
3 laterals	35	24	....	....	0.0	0.0	....	....
2 laterals	29	27	....	....	0.0	0.0	....	....
1 lateral	43	22	....	....	0.0	0.0	....	....
Tree H-2								
Open-pollinated clusters	396		....	....	....	....	5.1	
Terminal and 4 laterals	21	16	5.0	20.0	0.0	0.0	0.9	3.8
4 laterals	26	17	....	....	0.0	0.0	....	....
3 laterals	28	13	....	....	0.0	0.0	....	....
2 laterals	40	12	....	....	0.0	0.0	....	....
1 lateral	28	5	....	....	0.0	0.0	....	....

*Tree set a few fruits.

Open-pollinated clusters.—The Stayman trees in the Station orchards are admirably located for cross pollination and freedom from frost; therefore, it seemed reasonable to examine branches on open-pollinated trees to substantiate the results of the hand-pollination experiments. The data from selected limbs on 29 well-pollinated trees are arranged in Table 9 on the basis of vigor and cultural treatment. There was no evidence of frost injury to the flowers or partially developed fruits on the trees chosen.

TABLE 9.—Position and Percentage Set of Open-pollinated Flowers of Stayman Winesap—1925-1929

Vigor and treatment of trees	Number of trees	Age of trees	Clusters counted	Fruits counted	Percentage of fruits: Terminal	Percentage of fruits: Lateral	Flowers setting fruit: Terminal	Flowers setting fruit: Laterals	Flowers setting fruit: Entire cluster
1925—After second drop									
			Number	*Number*			*Percentage*	*Percentage*	*Percentage*
Weak—sod, no N	5	9	...	842	93.4	6.6	...	...	...
Moderately vigorous—sod, N	3	9	...	1015	66.9	33.1	...	...	...
Vigorous—sod, N	5	9	...	1015	86.2	13.8	...	...	...
Moderately vigorous—grass mulch, N	6	9-26	...	1455	87.9	12.1	...	...	...
Vigorous—grass mulch, no N	4	10	...	1268	71.1	28.9	...	...	...
Vigorous—cultivation, N and no N	6	10	...	1445	80.1	19.9	...	...	...
1926—After first drop									
Weak—sod, no N	3	10	560	158	72.1	27.9	20.4	2.2	6.3
Moderately vigorous—sod, N	2	10	451	213	60.7	49.3	23.9	5.8	9.5
Vigorous—sod, N	3	10	620	565	58.2	41.8	53.1	8.2	16.1
Vigorous—grass mulch, N and no N	4	11	460	287	74.9	25.1	46.9	3.4	11.3
Vigorous—cultivation, N and no N	2	11	409	339	67.8	32.2	56.2	4.3	15.1
1927—After first drop									
Vigorous—grass mulch, N	1	12	751	742	33.2	66.8	33.0	16.7	20.3
Vigorous—cultivation, N and no N	6	12	2864	3168	47.8	52.2	52.8	14.8	21.8
1928—After first drop									
Vigorous—sod, N	1	12	689	611	25.7	74.3	22.5	16.5	17.7
Vigorous—grass mulch, N	3	13	1066	1026	12.0	88.0	13.4	23.0	19.2
Vigorous—cultivation, N	2	10-14	1188	524	24.0	76.0	10.6	8.4	8.8
1929—After first drop									
Vigorous—sod, N	2	13	402	56	5.2	94.8	0.8	3.5	3.1
Vigorous—grass mulch, N	4	14-30	1180	750	12.0	88.0	7.6	16.0	14.2
Vigorous—cultivation, N	2	14	585	245	10.6	89.4	4.4	9.4	8.4
1929—After second drop									
Vigorous—sod, N	2	13	402	39	7.7	92.3	0.8	2.4	2.1
Vigorous—grass mulch, N	4	14-30	1180	511	13.7	86.3	5.9	10.7	9.6
Vigorous—cultivation, N	2	14	585	178	8.9	91.1	2.8	7.0	6.1

From 71.1 to 93.4 per cent of the fruits on these trees, after the June drop, were terminal in position. This second drop had been light and so the results were fairly representative of the set after the first abscission period. On all trees of low vigor, the highest percentage of the fruits was terminal in position; the laterals were apparently unable to set as well in competition with the terminals as on the more vigorous trees.

Considering the data of both the hand- and open-pollinated Stayman flowers, it was evident that a far greater proportion of the terminals set fruit than laterals when the clusters were undeflorated. No experiment was made to determine the effect of competition between less than four laterals and the terminal upon the set of the laterals.

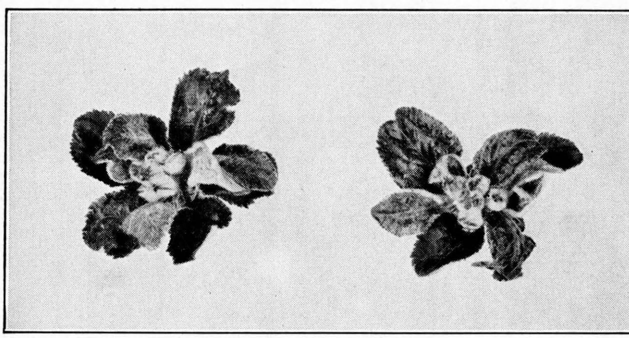

Fig. 3.—State of development of Jonathan flowers at time of defloration, May 4, 1926

Defloration of Jonathan clusters in 1925 and 1926.—For comparison with Stayman Winesap, one defloration was made on Jonathan trees in 1925 and 1926 just as the tips of the laterals were showing pink (Fig. 3). One to five laterals were left in a cluster.

The data are given in Table 10. On the vigorous trees, 408-7 and 408-9, the percentage set of the various laterals was considerably greater than that of the corresponding number in Stayman. Furthermore, in marked contrast to Stayman, the lateral flowers singly and in undeflorated clusters set practically as well as the terminal.

Moreover, it is to be noted that the complete clusters, when hand pollinated, set as well as the open-pollinated clusters, which would indicate that emasculation had little or no effect upon the set of Jonathan flowers.

TABLE 10.—Effect of the Number and Position of Flowers in the Cluster Upon the Percentage Setting Fruit

After first drop—Jonathan—1925, 1926

Number and position of flower	Clusters pollinated	Flowers setting fruit					
		Terminal		Laterals		Entire cluster	
		After 1st drop	After 2nd drop	After 1st drop	After 2nd drop	After 1st drop	After 2nd drop
Tree 408-7—1925							
	No.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Open-pollinated clusters	26	38.5	....	19.3	....	22.2	....
Terminal and 4 laterals	43	28.0	....	26.8	....	27.0	....
4 laterals	38	....	....	25.6	....	....	....
3 laterals	51	....	....	31.3	....	....	....
2 laterals	51	....	....	51.0	....	....	....
1 lateral	53	....	....	60.3	....	....	....
Tree 408-3—1925							
Open-pollinated clusters	23	30.4	....	23.7	....	24.6	....
Terminal and 4 laterals	25	24.0	....	22.0	....	22.3	....
4 laterals	43	....	....	23.2	....	....	....
3 laterals	61	....	....	25.7	....	....	....
2 laterals	39	....	....	24.3	....	....	....
1 lateral	65	....	....	44.6	....	....	....
Tree 408-9—1926							
Open-pollinated clusters	80	....	....	....	....	31.3	21.1
Terminal and 5 laterals	56	....	....	....	....	38.6	23.2
5 laterals	76	....	....	26.6	16.1	....	....
4 laterals	99	....	....	32.3	21.9	....	....
3 laterals	119	....	....	38.6	28.8	....	....
2 laterals	97	....	....	40.7	29.4	....	....
1 lateral	120	....	....	44.2	34.2	....	....
Terminal	42	50.0	33.3	....	....	....	....

COMPETITION BETWEEN TERMINALS AND LATERALS

Defloration of Stayman clusters in 1926.—In 1926 experiments were undertaken to determine the effect of the terminal upon the set of one competing lateral.

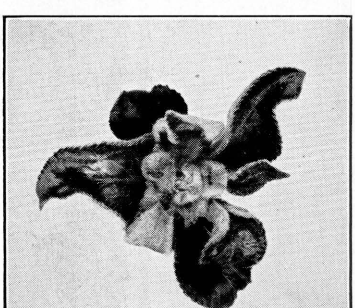

Fig. 4.—Stage of development of flowers at time of defloration, Tree 8-8. May 5, 1926.

Only one defloration was made as the flowers of the clusters were separating (Fig. 4).

The data are given in Table 11. On the vigorous trees, 149 and 8-8, one lateral flower in competition with the terminal gave a poor set (Figs. 5 and 6). On the tree of low vigor, I-3, not even the terminal flowers of the hand-pollinated clusters set fruit.

Open-pollinated clusters of Stayman Winesap.—Selected limbs on open-pollinated trees were again examined to determine the number and position of the flowers setting fruit. No frosts occurred, and the weather conditions during bloom were favorable for cross pollination.

TABLE 11.—Effect of the Number and Position of Flowers in the Cluster Upon the Percentage Setting Fruit

After first drop—Stayman Winesap—1926, 1927

Number and position of flowers	Clusters pollinated	Flowers setting fruit		
		Terminal	Laterals	All flowers
Tree 149—1926				
	Number	*Percentage*	*Percentage*	*Percentage*
Terminal and 1 lateral	48	37.5	2.1	19.8
Terminal	41	17.1	......	......
2 laterals	34	......	0.0	0.0
Open-pollinated clusters	158	43.6	1.3	8.2
Tree 8-8—1926				
Terminal and 1 lateral	82	35.4	8.5	22.6
Terminal	71	22.5	......	......
2 laterals	191	......	7.7	7.7
Open-pollinated clusters	309	51.8	6.4	15.1
Tree I-2—1926				
Terminal and 1 lateral	94	0.0	0.0	......
2 laterals	126	0.0	0.0	......
Open-pollinated clusters	45	......	......	3.5
Tree 637—1927				
Terminal	44	72.7	......	......
1 lateral	40	......	47.5	......
Terminal and 1 lateral	25	68.0	0.0	34.0
2 laterals	40	......	22.5	22.5
Terminal and 2 laterals	35	68.6	1.4	23.8
3 laterals	44	......	9.1	9.1
Tree 8-10—1927				
Terminal	64	50.0	......	......
1 lateral	57	......	50.9	......
Terminal and 1 lateral	80	48.8	21.2	35.0
2 laterals	66	......	38.6	38.6
Terminal and 2 laterals	17	76.5	14.7	33.3
3 laterals	21	......	20.7	20.7
Terminal and 3 laterals	35	42.8	7.6	16.4
4 laterals	49	......	21.4	21.4
Tree 8-3—1927				
Terminal	54	55.5	......	......
1 lateral	114	......	71.9	......
Terminal and 1 lateral	34	58.2	8.2	33.8
2 laterals	90	......	36.1	38.1
Terminal and 2 laterals	14	71.4	7.1	28.6
3 laterals	26	......	20.5	20.5
Terminal and 3 laterals	24	41.6	16.7	22.5
4 laterals	20	......	13.8	13.8

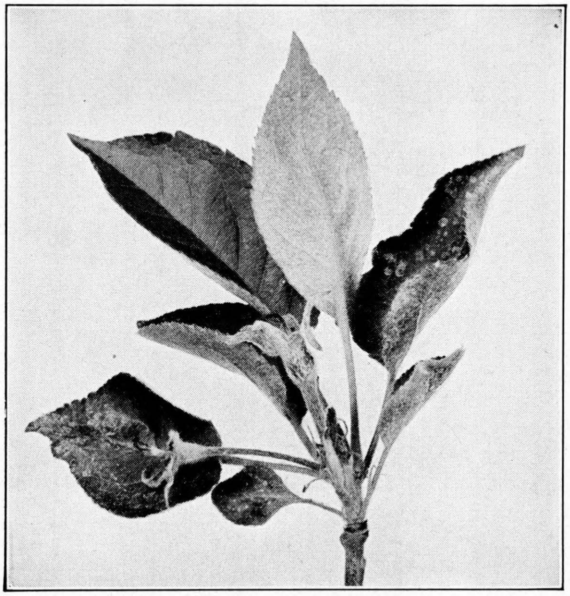

Fig. 5.—The terminal flower which has set in this cluster has prevented the setting of the lateral. (Notice calyx lobes not entirely removed.)

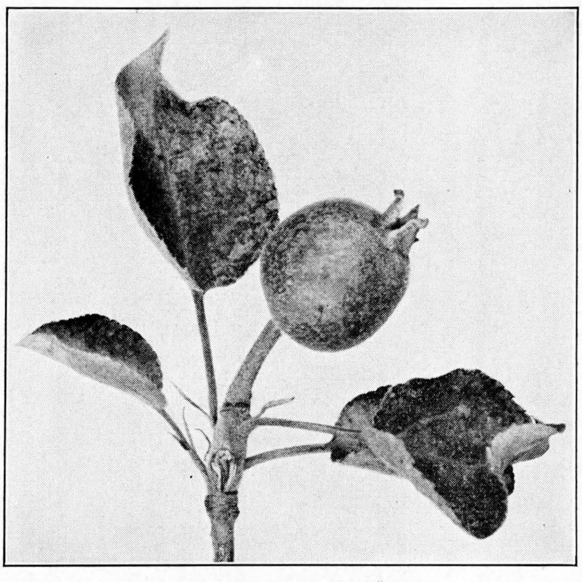

Fig. 6.—Fruit from terminal flower, Tree 149. June 17, 1926. (Notice calyx lobes were not removed in emasculating)

As in 1925, the greater proportion of the fruits was terminal in position (Table 9). It is to be noted that the trees of low vigor, in sod, showed the lowest percentage of flowers setting fruit. The trees of only moderate vigor set a slightly higher proportion, while the set on the vigorous trees ranged from 11.3 to 16.1 per cent.

In Table 12 data are presented to show the number and position of fruits on the fruit-bearing points of the selected branches, after the first abscission period. With the trees of low vigor, 99.3 per cent of the fruits were borne singly. Only on the more vigorous trees did bearing spurs and shoots with three fruits occur.

Defloration of Stayman clusters in 1927.—Although the data obtained in 1926 indicated that the set of laterals in competition with the terminals on the same cluster base was low, the hand-pollination results had not yet established the depressing effect of the terminal upon the set of varying numbers of laterals. Furthermore, the set of laterals alone was not as satisfactory as might be expected. This lower set was probably due to the fact that emasculation reduced the set of Stayman.

Consequently, in 1927 the experiments on the effect of the terminal upon the set of varying numbers of laterals were continued. The clusters were deflorated just as they had expanded sufficiently to permit separation of the flowers.

The results are also given in Table 11. On tree 8-10 one lateral flower alone on the cluster base set practically as well as the terminal alone. On tree 637 the terminal gave a higher percentage set; whereas on tree 8-3 the reverse was true. However, as the number of laterals in competition with the terminal was increased, the percentage of the flowers setting fruit decreased rapidly. The effect of the terminal in depressing the set of the laterals may be discerned by comparing the set of two laterals competing with the terminal with that of three laterals without the terminal. It is also interesting to note that the set of the terminal flowers showed practically no significant reduction as the number of competing laterals was increased.

The evidence, then, is very clear cut in showing that there is not only a marked competition between the laterals when the terminal is removed, but that there is also a much keener competition for water and food between the lateral and terminal flowers, in favor of the latter.

Open-pollinated clusters.—The open-pollination results obtained in 1927 were similar to those taken in 1926. They are also presented in Tables 9 and 12.

TABLE 12.—Number and Position of Fruit-bearing Points of Open-pollinated Trees
Stayman Winesap. 1926-1928

Vigor and treatment of trees	Percentage of fruit-bearing clusters with				Percentage of fruit-bearing clusters with fruits present on cluster base as						
	1 fruit	2 fruits	3 fruits	4 fruits	Terminal	1 lateral	Terminal and 1 lateral	2 laterals	Terminal and 2 laterals	3 laterals	4 laterals
1926—After first drop											
Weak—sod, no N	99.3	0.7	...	...	72.6	26.7	...	0.7	...	...	...
Moderately vigorous—sod, N	96.6	3.4	...	...	51.0	45.6	1.5	1.9	...	...	...
Vigorous—sod, N	80.3	17.8	1.9	...	52.4	27.9	8.4	9.4	1.5	0.4	...
Vigorous—grass mulch, N and no N	95.5	3.8	0.7	...	76.6	18.9	1.9	1.9	0.7	...	...
Vigorous—cultivation, N and no N	86.7	13.3	...	...	64.8	21.9	10.6	2.7	...	...	...
1927—After first drop											
Vigorous—grass mulch, N	86.1	13.3	0.6	...	35.4	50.7	2.5	10.8	0.2	0.4	...
Vigorous—cultivation, N and no N	84.4	13.0	2.2	0.4	48.5	35.9	7.0	6.0	1.0	1.2	0.4
1928—After first drop											
Vigorous—sod, N	70.3	26.4	3.3	...	27.7	42.6	6.7	19.7	...	3.3	...
Vigorous—grass mulch, N	80.8	17.7	1.4	0.1	16.3	64.5	0.7	17.0	...	1.4	0.1
Vigorous—cultivation, N	89.8	9.4	0.8	...	26.5	63.3	0.2	9.2	...	0.8	...
1929—After first drop											
Vigorous—sod, N	94.3	5.7	...	...	3.8	90.6	...	5.6	...	...	...
Vigorous—grass mulch, N	76.2	20.4	3.4	...	12.1	64.1	3.2	17.2	0.5	2.9	...
Vigorous—cultivation, N	90.1	9.9	...	...	9.8	80.3	1.9	8.0	...	...	...
1929—After second drop											
Vigorous—sod, N	98.3	1.7	...	...	5.1	93.2	1.7	...	...	...	...
Vigorous—grass mulch, N	90.4	9.4	0.2	...	16.0	74.4	1.1	8.3	...	0.2	...
Vigorous—cultivation, N	95.9	4.1	...	...	8.7	87.2	0.6	3.5	...	...	...

Contrary to expectation one-half to two-thirds of the fruit which set in 1927 was from lateral flowers. The terminals, however, showed two to four times higher percentage of flowers setting fruit. In undeflorated clusters the set was 20 to 21 per cent. As shown in Table 12, approximately 85 per cent of the fruit-bearing points had only one fruit after the first abscission period; a small number of the clusters on these vigorous trees had three and four fruits.

Defloration of Stayman clusters in 1928.—One defloration only was made on the vigorous trees 149, 622, and 616. On these trees the terminal flowers were pollinated just as they were opening sufficiently to expose the anthers. The defloration was not made until the laterals were pollinated, which was several days later. Due to this difference in time of pollination between the terminal and lateral, one would expect the depressing effect of the terminal upon the set of the laterals to be particularly evident.

The data of the three trees are presented in Table 13. The terminal flowers largely failed to set fruit in the hand-pollinated clusters, due to widespread pistil abortion which was practically impossible to recognize at the time of pollination. The set of the lateral alone on trees 149 and 616 was over 60 per cent. The set of two laterals on the spur with the terminal flower was also unusually high, due undoubtedly to the failure of the terminal as a competing factor. Furthermore, in the open-pollinated clusters on these trees the terminal flowers gave a small percentage set due to the above mentioned abortion.

Open-pollinated clusters in 1928.—The open-pollination results taken in 1928 are also presented in Tables 9 and 12. Seventy-four and three-tenths to 88 per cent of the fruits present after the first abscission period was lateral in position. The set of the terminal flowers was low, ranging from 10.6 to 22.5 per cent. On the other hand, the percentage set of the lateral flowers was as high as any year of the study. In Table 12 it is to be noted that a higher percentage of the fruiting points had two fruits than was observed at any time from 1926 to 1929. The two-fruited clusters were largely comprised of two laterals.

The evidence from both the hand- and open-pollinated trees in 1928 indicates that with the terminal flower lacking or aborted the set of laterals is increased and is sufficient to provide for a full commercial yield of fruit. In fact, practically the same set was obtained in undeflorated clusters with the terminals aborted as was obtained in 1926 and 1927 with a much higher percentage of the terminal flowers setting.

TABLE 13.—Effect of the Number and Position of Flowers in the Cluster Upon the Percentage Setting Fruit

Stayman Winesap. 1928

Number and position of flowers	Number of clusters		Flowers setting fruit					
			Terminal		Laterals		Entire cluster	
	After 1st drop	After 2nd drop	After 1st drop	After 2nd drop	After 1st drop	After 2nd drop	After 1st drop	After 2nd drop
Tree 149								
			Percentage	*Percentage*	*Percentage*	*Percentage*	*Percentage*	*Percentage*
1 lateral	97	80	...	...	63.9	50.0	...	...
3 laterals	92	86	...	...	20.6	15.9	20.6	15.9
Terminal and 2 laterals	99	91	2.0	0.0	34.3	28.0	23.6	18.7
Open-pollinated clusters	167	...	0.2	...	11.4	...	9.6	...
Tree 616								
1 lateral	113	94	...	...	61.1	21.2	...	...
3 laterals	149	104	...	...	19.7	6.7	19.7	6.7
Terminal and 2 laterals	91	66	0.0	0.0	41.2	9.9	27.4	6.5
Open-pollinated clusters	230	...	10.9	...	11.6	...	11.4	...
Tree 622								
1 lateral	148	146	...	...	27.0	8.9	...	...
4 laterals	230	198	...	...	11.4	5.1	...	...
Terminal and 3 laterals	106	99	1.9	1.9	8.8	2.7	7.1	2.5
Open-pollinated clusters	359	...	6.7	...	8.1	...	7.8	...

DEFOLIATION AND DEFLORATION EXPERIMENTS

Defoliation and defloration of Stayman in 1929.—The number of flowers in a Stayman Winesap cluster varies from 3 to 7. The clusters on vigorous trees have 5 to 7, while the trees low in vigor have 3 to 5 flowers. Heinicke (23) pointed out a similar relationship between vigor and the number of flowers to a cluster in Baldwin and Rhode Island Greening.

The flower cluster of the apple is corymb-like with a terminal flower. Bijhouwer (3) reported that in the mixed bud there are usually 21 leaf formations inserted in spiral sequence. They are, in order: 9 bud scales, 3 transitional leaves, 5 to 6 foliage leaves, and 3 to 4 bracts. The lowest one of the foliage leaves has no bud in the axil, while the next two each have a secondary axis. In the axils of the next two foliage leaves towards the apex, as well as in those of the succeeding bracts, are flowers. The terminal flower of the cluster opens first, followed by the two lowest laterals, each of which has a subtending leaf. In some six-flowered clusters the third lateral from the base has a foliage leaf rather than a bract. This lateral is the next to open and is followed closely in order by the upper laterals in the axils of the bracts.

Up to 1929 the earliest opening and largest laterals were selected for pollination. Undoubtedly, when no more than three laterals were left to a cluster the three lower ones were usually chosen. These opened at practically the same time. Aside from selection according to size and degree of opening, no attempt was made to pollinate laterals within a particular phyllotactic position.

In 1929, the experiments were undertaken to determine the ability of laterals of a particular position to set fruit when alone on the cluster base or when in competition with laterals in other positions. It was found that, in order to do the amount of work desired within the time available, it would be impossible to distinguish between the lower laterals, each of which was in the axis of a subtending leaf (Fig. 7). In consequence, in the deflorations no attempt was made to choose between these two laterals provided

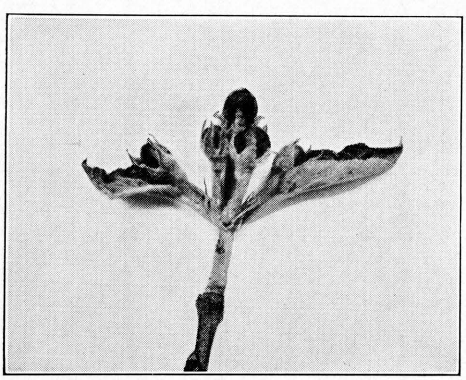

Fig. 7.—Cluster of Stayman showing subtending leaves of the lower laterals. April 19, 1928

they opened simultaneously and had the subtending foliage leaf. The small lateral adjacent to the terminal was not used in the 1929 experiments.

Detjen (11) reported data on the effect of position of the laterals of Stayman Winesap on their ability to set. These results indicated that the small lateral next to the terminal and without a leaf had the least chance to set of all the flowers of the cluster, regardless of position. The data concerning the other laterals were not significantly different.

The deflorations and pollination were carried out just as the laterals were opening to expose the anthers.

The data are presented in Table 14. On trees 147 and 149 the terminal flower gave a higher percentage set than any lateral alone.

On tree 147, after the second drop the upper lateral alone set as well as the lower lateral under similar isolation. On tree 149, the lower lateral set a significantly higher percentage. The data from both trees indicated that the large, upper lateral was at a disadvantage when competing on the same cluster base with one lower lateral. When the upper lateral was competing with the terminal, it usually abscised. The lower lateral under similar competition set fairly well.

Detjen (11) suggested that the presence of the subtending leaf might be the decisive factor in the relative ability of laterals to set fruit. In order to substantiate this, the experiment on tree 8-11 was undertaken to determine the effect of removing the subtending leaf on the subsequent ability of the lateral to set fruit.

From the data in Table 14, it is to be noted that the set of the lower lateral was only slightly influenced by the removal of its subtending leaf. One lateral only was present on the cluster base. On this tree the large, upper lateral failed to set as well as the lower lateral either with or without its leaf.

Open-pollinated clusters in 1929.—In 1929, examination of the flowers and fruits on selected limbs of a few open-pollinated trees was made. The data are given in Tables 9 and 12. This year the smallest percentage of the fruits was terminal in position of any year of the study, due probably to pistil abortion (Table 9). The lateral flowers gave higher percentage sets than the terminals. Again, as in the previous years, the greater proportion of the fruit-bearing points had only one fruit (Table 12).

TABLE 14.—Effect of Position of Flower and Subtending Leaf Upon Setting of Fruit

Stayman Winesap. 1929

Position of flowers	Clusters pollinated	Flowers setting fruit					
		Terminal		Lower lateral		Upper lateral	
		After 1st drop	After 2nd drop	After 1st drop	After 2nd drop	After 1st drop	After 2nd drop
Tree 147							
	Number	*Percentage*	*Percentage*	*Percentage*	*Percentage*	*Percentage*	*Percentage*
Terminal	97	13.4	8.2	...	...	...	...
Lower lateral	113	...	...	3.6	0.8	...	...
Large upper lateral	108	...	...	...	...	1.9	0.9
2 lower laterals	195	...	...	6.3	3.7	...	...
Large upper and 1 lower lateral	119	...	...	3.1	0.0	0.8	0.0
Terminal and 1 lower lateral	114	4.4	3.5	3.5	0.8	...	...
Terminal and large upper lateral	97	3.1	1.0	...	...	0.0	0.0
Tree 149							
Terminal	96	20.8	11.5	...	...	...	...
Lower lateral	103	...	...	9.7	6.8	...	...
Large upper lateral	93	...	...	...	...	12.9	3.2
2 lower laterals	112	...	...	8.5	6.2	...	...
Large upper and 1 lower lateral	108	...	...	6.5	1.9	5.6	0.9
Terminal and 1 lower lateral	102	15.7	13.8	6.8	5.9	...	...
Terminal and large upper lateral	193	19.3	14.0	...	...	1.6	0.0
Tree 8-11							
Large upper lateral	103	...	...	...	...	24.3	12.7
1 lower lateral with leaf	133	...	...	39.0	33.5	...	...
1 lower lateral with leaf removed	146	...	...	39.8	26.5	...	...

In view of the results obtained with the hand-pollinated lateral flowers within a particular phyllotactic position, observations were made of the position of the lateral, open-pollinated flowers which survived the two abscission periods. These results are given in Table 15. It is to be noted that the lower lateral flowers gave a much higher percentage set under competitive conditions on undeflorated flowering points than the upper laterals with bracts. This substantiates the data from the controlled experiment.

TABLE 15.—Position of Laterals Which Have Set After First and Second Drops

Open-pollinated trees, Stayman Winesap. Wooster—1929

Tree number	Lateral fruits on selected limbs		Percentage of fruits			
			Upper		Lower	
	After 1st drop	After 2nd drop	After 1st drop	After 2nd drop	After 1st drop	After 2nd drop
	Number	*Number*				
1-9	90	61	15.6	14.7	84.4	85.3
1-11	129	101	17.8	15.8	82.2	84.2
4-2	111	82	11.2	9.7	88.8	90.3
4-9	88	86	28.4	30.0	71.6	70.0
8-8	....	20	....	30.0	....	70.0
8-11	43	28	17.2	38.9	82.8	61.1
E-5	11	9	9.9	0.0	90.1	100.0
158	251	117	25.1	17.1	74.9	82.9
163	....	86	....	30.0	....	70.0
426	206	156	17.5	14.1	82.5	85.9

Defoliation and defloration experiments in 1930.—In 1930, the experiments were outlined to obtain further information on: (1) the relative ability of the upper laterals and of the lower laterals to set fruit; and (2) the influence of the subtending leaf on the ability of a lateral to set.

Defloration and pollination were carried out just as the laterals were opening. In a considerable number of clusters the subtending leaf was removed from the lower lateral when alone and when competing with the large, upper lateral. The set from such laterals was compared with that of laterals under similar conditions but with leaves intact. Furthermore, for the first time in the experiments, the lateral adjacent to the terminal flower was selected to compare its set with that of the largest lateral with a bract.

The results are given in Table 16. On all trees the lower lateral with its leaf intact gave a higher percentage set than the largest, upper lateral when each was alone on the cluster base. Under competitive conditions the upper lateral was at a disadvantage. However, on tree 212 with the removal of the subtending leaf from the lower lateral its set dropped considerably below that of the upper lateral when competing on the same cluster base. On tree 637 the differences were not so marked; on tree 212 removal of the subtending leaf appreciably reduced the set of the lower lateral, even when alone; on tree 637 removal did not affect the set. As was expected, the small, upper lateral adjacent to the terminal failed to set as well as the largest, upper lateral, even when isolated from all other flowers.

TABLE 16.—Effect of Position of Flower and Subtending Leaf Upon Setting of Stayman Winesap
1930

Position of flowers	Clusters pollinated	Flowers setting fruit: Lower lateral, After 1st drop	Flowers setting fruit: Lower lateral, After 2nd drop	Flowers setting fruit: Upper lateral, After 1st drop	Flowers setting fruit: Upper lateral, After 2nd drop
Tree 212—1930					
	Number	*Percentage*	*Percentage*	*Percentage*	*Percentage*
Large upper lateral	99	....	....	39.4	38.4
1 lower lateral with leaf	96	63.5	63.5	....	....
1 lower lateral with leaf removed	118	56.8	55.9	....	....
Large upper and lower lateral with leaf	98	43.9	40.8	33.7	29.6
Large upper and lower lateral with leaf removed	81	19.7	19.7	32.1	32.1
Tree 637—1930					
Large upper lateral	96	....	....	12.5	8.3
1 lower lateral with leaf	102	17.6	9.8	....	....
1 lower lateral with leaf removed	86	14.0	12.8	....	....
Large upper and lower lateral with leaf	98	9.3	6.2	4.1	3.1
Large upper and lower lateral with leaf removed	91	9.9	8.8	8.8	4.4
Tree 8-10—1930					
Large upper lateral	185	....	....	12.4	9.7
Small upper lateral	103	....	....	8.8	4.9
1 lower lateral	184	20.1	16.3	....	....
2 lower laterals	102	11.7	10.3	....	....
Large upper and 1 lower lateral	86	5.8	4.6	3.5	3.5
Tree 8-8—1930					
Large upper lateral	104	....	....	24.0	16.4
1 lower lateral	96	42.7	34.4	....	....
Large upper and 1 lower lateral	120	26.7	20.0	10.0	7.5

EFFECT OF SELF AND CROSS POLLINATION ON FRUIT SETTING

The data presented in the literature review indicate that Stayman Winesap has a very low degree of self fruitfulness. Practically all investigators selfed individual clusters on open-pollinated trees, but Ewert (17, 18, 19) has repeatedly stated that more fruits are to be expected from selfing entire branches and trees than from selfing individual clusters adjacent to open-pollinated clusters. In support of this, the writer has observed in his pollination work prior to 1929 that more fruits were obtained with some varieties by selfing larger units than by selfing single clusters on open-pollinated trees. It is possible that the nutritional conditions of flowers on a selfed limb or tree are different from those of selfed flowers on a single spur competing with many crossed flowers on adjacent spurs. In the latter case, the flowers would likely undergo a more severe competition for food and water than flowers on a limb entirely selfed.

The pollination experiments on Stayman in 1929 to 1931 were undertaken to determine the relative degree of self fruitfulness of a number of varieties, using larger units than employed in the experiments reported in 1927. In addition, the comparative effectiveness of several varieties as pollinizers of Stayman was determined.

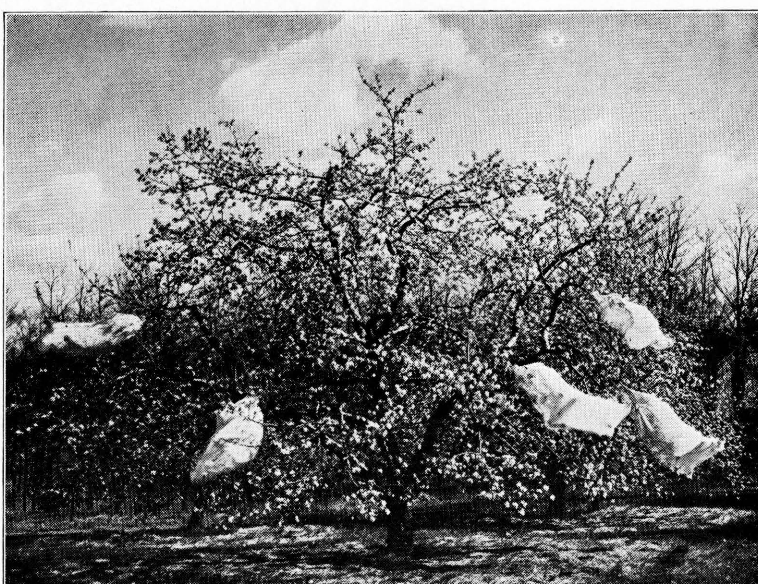

Fig. 8.—Stayman tree showing method of determining degree of self fruitfulness and suitable pollinizing varieties. Tree 158

Cheesecloth bags, 6 feet long and 3 feet wide, were used to enclose large limbs (Fig. 8). These limbs were carefully selected for the same diameter and vigor. The bags were placed over the branches just as the terminal flowers were opening and were removed as the last of the petals were falling. The clusters were partially deflorated. In the 1929 crossing experiments, the terminal on tree 158 and one large lateral on tree 8-11 were pollinated. In 1930 and 1931 two laterals were pollinated. There was no emasculation.

TABLE 17.—Pollination of Stayman Winesap
1929-1931

Pollen variety	Flowers pollinated	Flowers setting fruit		
		After 1st drop	After 2nd drop	At maturity
Tree 158—1929				
	Number	*Percentage*	*Percentage*	*Percentage*
Stayman	370	2.1	0.6	0.6
Delicious	61	21.3	9.8	9.8
Gallia Beauty	69	23.2	13.0	13.0
Grimes Golden	99	16.1	12.1	10.1
Jonathan	87	19.5	12.6	12.6
Open-pollinated clusters	1639	16.2	8.7	8.7
Tree 8-11—1929				
Delicious	92	25.0	20.6	19.6
Jonathan	115	13.9	13.0	13.0
Open-pollinated clusters	1112	4.1	2.7	2.7
Tree 212—1930				
Stayman	450	0.0	0.0	0.0
Delicious	158	10.7	10.2	10.1
Starking	156	5.1	4.5	4.5
Jonathan	114	11.4	10.5	9.7
Open-pollinated clusters	743	5.1	5.0	5.0
Tree 158—1931				
Turley	191	0.5	0.5	....
Jonathan	216	8.8	8.8	....
Golden Delicious	196	21.9	18.4	....
Open-pollinated clusters	1155	16.8	11.1	....

RESULTS FROM SELFING STAYMAN

On tree 158 a small percentage set was obtained by selfing, but no fruits set from selfed flowers in 1930 (Table 17). From selfing Baldwin, Grimes, Jonathan, and Rome, however, in 1929 and using the same method an appreciably larger set was obtained (28).

RESULTS FROM CROSS POLLINATION OF STAYMAN

Percentage of flowers setting fruit.—On the basis of the percentage of flowers setting fruit there was no significant difference in the effectiveness of the varieties Delicious, Grimes, Jonathan, and Gallia Beauty as pollinizers in 1929. Delicious gave a lower set than Jonathan on tree 158, but a higher set on 8-11. This indicates the importance of the female parent in such experiments, since pollen from the same vial was used on both trees.

In 1930, the sample of Starking pollen used was rather old and at the time of pollination did not germinate well. The percentage set obtained was somewhat lower than that of Jonathan and Delicious.

In 1931, Turley, supposedly similar to Stayman, but with fruit of higher color, produced no fruit as a pollinizer. On the other hand, Jonathan and Golden Delicious gave satisfactory results. The Golden Delicious pollen was applied to two laterals on May 8 when they were just opening. The Jonathan pollen was applied on May 15 to the two laterals in each cluster which appeared to have receptive pistils. At this time, the earlier opening laterals were dropping their petals with the slightest touch.

Seed content of fruits produced by various pollinizing varieties.—The seed content of the fruits resulting from the various pollinizers is taken as another index of their relative effectiveness. Distinction was made between the well-filled, plump seeds and those showing only partial development of the cotyledons and embryo. The data are given in Table 18.

TABLE 18.—Relation of Pollen Variety to Number of Seeds and Percentage Germinating

Tree number	Pollen variety	Well-filled seeds per fruit	Flattened seeds per fruit	Well-filled seeds germinating
		1929		
		Number	*Number*	*Percentage*
158	Delicious	5.3±.303	1.0	34.4
	Gallia Beauty	4.8±.314	0.3	14.3
	Grimes Golden	4.0±.343	0.6	28.6
	Jonathan	4.0±.230	0.4	36.4
	Stayman Winesap	0.0	1.5	0.0
	Open-pollinated	4.1±.262	1.0	36.0
8-11	Delicious	4.4±.291	1.5	45.9
	Jonathan	4.9±.254	0.8	27.0
	Open-pollinated	3.5±.337	....	....
		1930		
212	Delicious	2.0±.310	3.8±.263	....
	Starking	3.3±.262	3.0±.385	....
	Jonathan	3.3±.279	3.2±.299	....
	Open-pollinated	3.6±.105	2.8±.104	....

When all trees are considered, there is no significant difference in either year between the seed content of the fruits produced by the various pollinizers. It is interesting to note that in 1930 a greater proportion of the seeds showed only partial development of the cotyledons and embryo.

Percentage of seeds germinating.—The percentage of well-filled seeds germinating was taken as a possible index of the relative effectiveness of the various varieties as pollinizers of Stayman. The seeds were placed between moistened blotting paper in petri dishes in 1930 and exposed to temperature conditions favorable for germination. Seeds which produced a hypocotyl at least one-sixteenth of an inch in length were counted as germinating.

The results are given in Table 18. With the exception of Gallia Beauty, which is, nevertheless, an effective pollinizer of Stayman, all varieties gave a germination within the range of 27 to 46 per cent.

EFFECT OF CHROMOSOMAL IRREGULARITIES IN MEGASPOROGENESIS

After the defloration experiments in 1925, the reason for the failure of Stayman to set as effectively as Jonathan became an important consideration. Since 1925, flowers and young fruits from hand- and open-pollinated clusters have been collected in order to study ovule and embryo development. Since 1926, the flowers have been taken sufficiently early to include megasporogenesis.

Although the detailed results of the microscopical study are to be published shortly, they are sufficiently included here to show their importance as a fruit-setting factor in Stayman Winesap.

The cytological examination of the meiotic divisions shows that irregularities commonly occur in megasporogenesis. These are of a nature which results in the development of many functionless spores and gametes, as well as embryos which are weak and unstable. Many of the seeds produced either fail to germinate or result in weak seedlings. In Jonathan, on the other hand, irregularities in meiosis were scarce.

The microscopical examination also indicated that the first abscission period is comprised of flowers which have not been fertilized, as well as of a large number in which only one to three egg nuclei have been fertilized. The size of the individuals at abscission depended, in large part, upon the number of ovules fertilized and the extent of embryo development.

The severity of the first drop in Stayman is correlated with the irregularities in megasporogenesis, acting in conjunction with an insufficient food and water supply for all flowers of a cluster. In Jonathan, the competition between flowers is not complicated by irregularities in megasporogenesis.

Because of their influence on fertilization and embryo development these irregularities are also a factor affecting the severity of the second drop.

ABSCISSION PERIODS IN STAYMAN WINESAP

It has been generally observed that there is a very heavy abscission of flowers shortly after petal fall. At times the fruit grower has expressed surprise that it is so much heavier than in Jonathan. In the experiments reported herein, the set of undeflorated clusters averaged approximately 15 per cent (Tables 8, 9, 11, 13, 17). With a five-flowered cluster this percentage is equivalent on an average to less than one fruit to a flowering point. Ballard (2), Auchter (1), Dorsey (14), and Vinson (46) obtained percentage sets equivalent to one fruit or less to a flower-bearing point. In addition, the open-pollination data from 1926 to 1929 (Table 12) show that over 70 per cent of the fruiting points had only one fruit after the first drop.

In 1928 and 1929, from petal fall until all abscission had ceased the drops were collected daily from a young, Stayman tree. This tree is in a vigorous condition and bears annually. The abscising flowers and partially developed fruits were collected on cheesecloth sheets spread beneath the tree. The branches were not shaken. The weather records during the abscission periods are given in Tables 19 and 20. The number of fruits abscising daily is plotted graphically in Figures 9 and 10.

In 1928, one large wave of abscission occurred from May 22 to June 15. The flowers falling from May 22 to 28 were almost entirely from the terminal position of the clusters; May 28 was the day of heaviest terminal abscission. The day of heaviest lateral abscission was June 2, when a strong wind brought off flowers which normally would have abscised the 2 days following. Rain and spraying from June 4 to 6 caused many to abscise which would have fallen from the 7th to the 10th. The flowers falling up to June 2 were unenlarged, while those abscising thereafter, up to June 15, showed a slight increase in size, up to .32 inch in diameter. This was a very small increase over the diameter at full bloom.

Figure 9 shows that a second period of abscission occurred from June 16 to July 5. The number falling was much less than at the first period; yet in total weight, as Detjen and Gray (12) have indicated, it was much more severe than the first drop. As shown in Table 19, the size of the drops increased as time progressed. Table 21 indicates also that the number of seeds per fruit increased in the larger individuals.

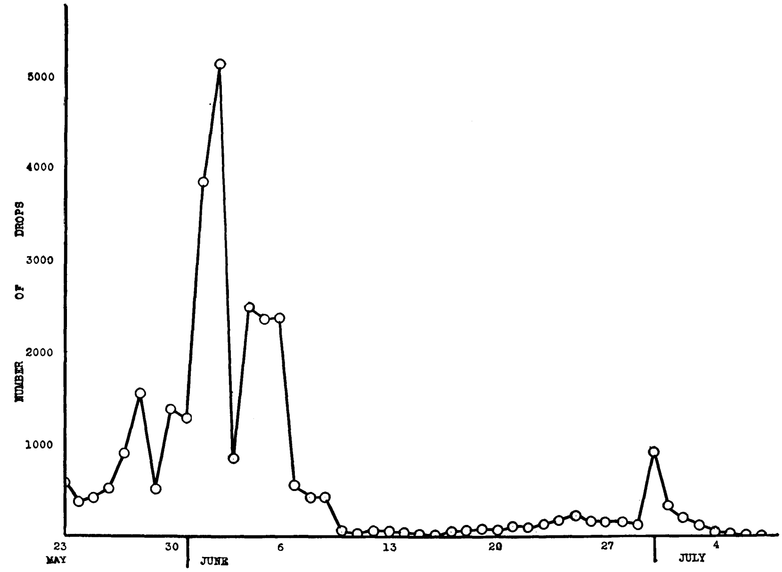

Fig. 9.—Graph showing daily abscission in Stayman Winesap, 1928

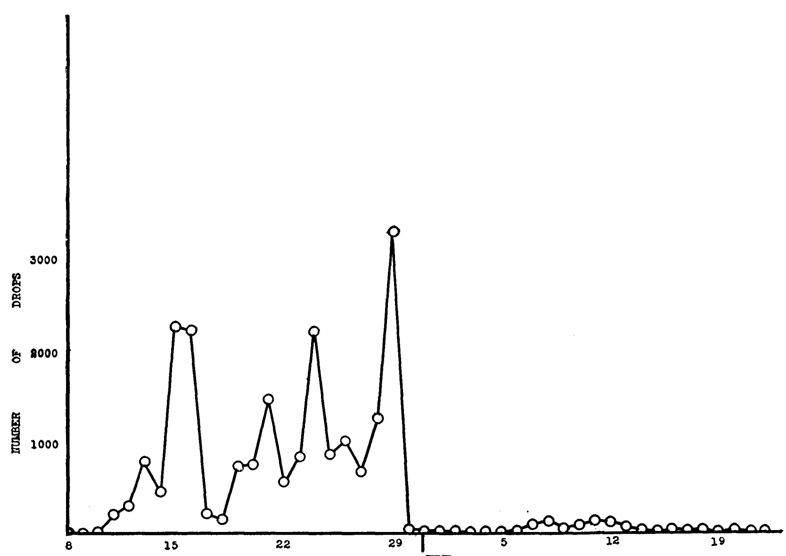

Fig. 10.—Graph showing daily abscission in Stayman Winesap, 1929

TABLE 19.—Weather Record During the Abscission Period
Tree C4-9—1928

Date	Rainfall	Diameter of drops	Notes
	In.	*In.*	
May 22			No dropping.
23			Very windy during entire day. First flowers abscising—all terminals.
25	.24		Terminal flowers only abscising.
26			Terminal flowers only abscising.
28	.11		Heavy abscission—practically all terminals.
29			Majority of flowers not laterals.
31	.15		Practically all drops unenlarged.
June 2	.18		Very windy.
3			A few drops slightly enlarged.
4	1.13		Rain and wind caused considerable abscission.
5	.32		Tree sprayed—hastened dropping.
6	.82	.06	Rain and wind brought down many drops.
			Drops now slightly enlarged.
7	.21		
8	.20		
9	.23		
12			Drops slightly enlarged—end of first drop.
14	.03		
16		.31-.43	
18	.63	.37-.50	Rain brought down many drops.
19	.06		
21		.37-.50	
22		.37-.63	
23	.38	.50-.75	
24	.02	.50-.94	
26	.05	.50-.94	Average size 0.69 inches.
29	1.00		
30	.01		
July 4	1.33		
9	.08		

In 1929 (Fig. 10), there was more variation than in 1928 in the number of flowers abscising daily during the first abscission period. Up to May 15 the drops were almost entirely terminal. The day of heaviest terminal abscission was May 15. The drops were unenlarged up to May 24. As in 1928, the latter part of the first abscission period was comprised of individuals ranging in diameter up to 0.32 inch (Table 20). After the first period, the set on the tree was 14.4 per cent.

The second period of abscission in 1929 ranged from June 6 to 22. It was very light compared to the drop in 1928 and was more nearly normal. In the end, the set was 10.8 per cent. After thinning, this was reduced to 8.0 per cent.

Detjen and Gray (12) presented an abscission curve for Stayman in 1927 similar to that in Figure 9 of this bulletin. The curve showed a prominent early crest, possibly due to terminal abscission. He concluded that there was only one period of abscission in Stayman on the basis of numbers, but two on the basis of weight. To the writer, the graph presented by Detjen also shows two periods on the basis of numbers, though to be sure there may be only a day or two in which few or no fruits abscise. In 1928 and 1929 there were several days, however, in which no abscission occurred.

TABLE 20.—Weather Record During the Abscission Period
Tree C4-9—1929

Date	Rainfall	Diameter		Notes
		Sets	Drops	
	In.	*In.*	*In.*	
May 7	.04			Petals not yet fallen from late blooming flowers.
8				Many terminals loosening but not yet abscising.
9				Terminals on great numbers of clusters about to abscise.
11				First flowers fall.
12	.35			
13	.02			Only enlarged terminals abscising.
14	.58			
15	1.00			End of terminal abscission.
16	.01			Very windy.
19	.93			Very windy.
21	.45			
22				Drops still unenlarged.
23				Drops still unenlarged.
24	.11	0.31	.13-.19	Few drops slightly enlarged.
25		0.31-.37	.13-.25	Unenlarged flowers all abscised.
28	.11			
29		0.50-.56	.19-.31	Rains of previous day hastened considerable abscission.
31				End of first drop.
June 8	.19		.31-.43	
9			.37-.50	
10		0.81	.37-.50	
12	.03			
13			.43-.63	
14	.23			
16	.01			
17			.50-.63	
19	1.33			
20	.40			
27		1.50		

TABLE 21.—Effect of Seed Content Upon June Drop of Stayman Winesap
1928

Date	Number of fruits	Average number of well-filled seeds per fruit	Average number of flattened seeds per carpel	Average number of all seeds per fruit
June 27	38	3.6	1.4	5.0
June 28	97	3.9	1.4	5.3
June 29	100	3.8	1.4	5.2
June 30	99	4.0	1.3	5.3
July 1	104	4.2	1.4	5.6
July 2	101	4.2	1.4	5.6
July 3	99	4.3	1.4	5.7
July 5	16	4.4	1.4	5.8

DISCUSSION OF FACTORS AFFECTING FRUIT SETTING

COMPETITION BETWEEN THE FLOWERS AND YOUNG FRUITS FOR FOOD AND WATER

The results of the defloration experiments show that between the flowers of Stayman competition for growth-producing materials was sufficiently large to influence effectively the number abscising during the first drop. In undeflorated clusters of both hand- and open-pollinated flowers, the set after the first drop was usually 15 per cent, or below. The experiments have indicated that the severity of such abscission is not the result of either ineffective cross pollination or of low tree vigor but of competition between the flowers of the cluster acting in conjunction with chromosome irregularities at megasporogenesis. Only when the clusters were partially deflorated was the percentage of flowers setting fruit markedly increased.

Furthermore, in this competition, the terminal flower usually had the advantage. When it was present and uninjured it depressed the set of the lateral flowers. Only on the more vigorous flowering points did competing laterals set fruit. It is probable that this competition between the terminal and lateral flowers is caused by more favorable nutritional conditions for the terminal one. The failure of the laterals to compete successfully with the terminals was not due to earlier pollination of the laterals because they abscised in large numbers even when pollinated at the same time as the terminals.

In competition with the terminal, the laterals also differed among themselves in their ability to set. The set of the laterals with subtending bracts was depressed more than those with subtending leaves. The greater proportion of the laterals present on the cluster base with the terminals, after both the first and second drops, was made up of those laterals in the axil of subtending leaves.

With the terminal either lacking or present but with an abortive pistil, the competition was also sufficient to reduce the set. However, one or two laterals would set on the cluster base. Again, there was a difference in the ability of the laterals in different phyllotactic positions to set fruit. Either one of the laterals with subtending leaves, termed in this bulletin "lower laterals", depressed the set of the largest lateral with a subtending bract, termed "upper lateral". This depression occurred even though the large upper lateral was as large and opened as early as the lower laterals. Moreover, there was a difference in the ability of the upper laterals to set fruit in competition with the lower laterals. The smallest and latest lateral to open, the one adjacent to the terminal, did not set as well, even when alone on the cluster base, as its adjacent larger neighbor with a subtending bract.

That the subtending leaf of a lateral was the important factor in its ability to withstand competition has not been established. Removal of the leaf did depress the set of the lower lateral when competing with the larger of the laterals with a subtending bract. Under competitive conditions, the leaf did favorably influence the set. It is to be recalled that Detjen (11) suggested that the presence of the subtending leaf might be the decisive factor in determining the relative ability of laterals to set fruit. Although the data presented in this bulletin show that the leaf was a factor, it is probable that the size and diameter of the vascular tissue is more important.

PERIOD OF GREATEST COMPETITION BETWEEN FLOWERS

The defloration studies show that an increased set, which occurred with a progressive decrease in the number of flowers to a cluster, was obtained even when the deflorations were made just before full bloom. Since it has been found that the meiotic divisions of megasporogenesis occur just as the tips of the flowers are turning bronze (Fig. 3), it is evident that meiosis had occurred before the late deflorations. The period of competition which resulted in the heavy abscission of flowers shortly after petal fall occurred subsequent to full bloom. The competition for food and water up to full bloom was not sufficiently great to prevent flowers from setting fruit, provided the clusters were partially deflorated just as the flowers were exposing the anthers. Defloration at this time enabled a large proportion of single, large laterals to set fruit when thus relieved of competition with adjoining flowers.

SIGNIFICANCE OF THE DEFLORATION EXPERIMENTS TO FROST INJURY

The defloration experiments indicate that the killing of the terminal flowers by frost will not result in a decreased commercial crop. One of the lower laterals, if uninjured, will set fruit. If both the terminal and lower laterals are killed, the larger of the upper laterals will set in a considerable number of clusters.

ABSCISSION IN JONATHAN

In Jonathan, the abscission during the first drop was decidedly less severe than in Stayman Winesap, even though competition existed between the flowers of the Jonathan clusters. The lateral flowers comprised a greater proportion of the fruits set than in Stayman. These differences were not due either to variation in vigor or to emasculation. Furthermore, the flowers were hand pollinated with viable pollen of the same variety. The question arises as to the reason for the heavier drop in Stayman. Is it a matter of difference in the severity of the competition for food and water or does another factor complicate the effects of such competition?

CHROMOSOME IRREGULARITIES IN STAYMAN

The microscopical examination of the flowers showed that chromosomal irregularities occur in megasporogenesis of Stayman Winesap. In consequence, many weak and functionless spores and gametes are produced. These irregularities result, likewise, in the development of a considerable number of weak and unstable embryos which develop for a short time and then abort.

Furthermore, the embryos which did not abort were exceedingly variable, producing many seeds which would not germinate. As shown in Table 18, 46 per cent germination was the maximum obtained from the large, well-filled seeds. Dickson (13) and Maney (32) also pointed out in this connection that Stayman ranked low in seed content and that the seeds which did germinate produced weak seedlings.

Osterwalder (37, 38), Heinicke (23), and Sax (42) have pointed out the relationship between seed number and the ability of fruits to set. It has now become evident that seed development and fruit production in Pyrus and Malus are closely correlated in those varieties which do not have a pronounced tendency toward parthenocarpy. A factor resulting in the failure of fertilization in a considerable number of ovules and in the development of weak, unstable embryos in others is certain to affect fruit setting. These chromosomal irregularities in megasporogenesis of Stayman Winesap are, thus, a direct and important factor.

EFFECT OF IRREGULARITIES ON COMMERCIAL YIELD

It should be understood at this point that irregularities in chromosome behavior may not necessarily result in the reduction of the number of fruits equivalent to a full commercial crop. The experiments show that, on the average, one fruit to every third flowering cluster is sufficient for a full commercial yield. On the basis of a five-flowered cluster, this is equivalent to 6.7 per cent set. The data indicate that after the first abscission period, on the more vigorous trees the set is usually 10 to 20 per cent. This is approximately equivalent to one fruit to each one or two flowering points. When the second period is normal 8 to 10 per cent of the fruits usually develop to maturity. There is thus a margin of about 2 to 4 per cent between the set after the June drop and that required for full commercial yields. This margin, even on vigorous trees after all abscission has occurred, is considerably less than that of Jonathan. When the Stayman trees are low in vigor this margin may be entirely eliminated and less than a commercial crop produced.

The writer agrees with Crane and Lawrence (9) that triploidy and aneuploidy in apple varieties does not necessarily mean that such varieties are unproductive. The fact is to be emphasized, however, that chromosomal irregularities in megasporogenesis of any variety may necessitate particularly favorable nutritional conditions if the variety is to be continued commercially. These irregularities, in conjunction with severe competition between the flowers in a variety which shows no pronounced tendency to parthenocarpy, will probably result in low productivity in trees of low to moderate vigor. Observations and experience have shown that Stayman will produce full commercial crops if the trees are well cross pollinated and are making good growth. The data presented in this bulletin emphasize the importance of maintaining favorable nutritional conditions, together with adequate cross pollination.

OVER-VIGOROUS TREES IN RELATION TO FRUIT SETTING

The statement is commonly made that young trees are over vigorous and that this condition accounts for their failure to set fruit in proportion to the flowers produced. Fletcher (21) and Wallis (47) declared this to be a fact but presented no data to support the conclusion. It has previously been pointed out that Powell (39) obtained no fruits from pollinating Stayman with York Imperial, a variety known to have highly germinable pollen. He attributed the failure to set fruit to the fact that the trees were young, and he stated that they were consequently over vigorous. Since the work of Powell, others have occasionally referred to his data to substantiate this general conclusion.

There is no doubt but that the herbaceous type of plant may be rather easily stimulated to the excessive vigor which is associated with the abscission of flowers in large numbers. Apple trees which have reached the flowering age cannot be so easily over stimulated. It is even questionable whether such a thing as over vigor among trees during their first flowering years exists. Neither observation nor experiment leads to the conclusion that all young trees fail to set fruit during the first flowering years. Some varieties, such as Baldwin, Wealthy, Yellow Transparent, and Oldenburg, set three to four fruits to a cluster the first flowering year, provided the trees are well pollinated.

On the other hand, there are a number of varieties which exhibit a tendency to set an unsatisfactory proportion of their flowers at this early period. These varieties are Delicious, Stayman, Tompkins King, Arkansas, Rhode Island Greening, and Paragon. That these varieties fail to set fruit as satisfactorily as Jonathan and Wealthy because of an over-vigorous condition is highly questionable. In view of present knowledge, Stayman and Jonathan may receive the same cultural treatment; in other words, they are supposedly equally vigorous, but one responds with a satisfactory set while the other does not. Can it be possible that one variety is over-vigorous under the same treatment to which the other variety responds satisfactorily? If so, some other modifying factor must exist.

It is possible that the disproportionate abscission of Delicious, Stayman, Rhode Island Greening, Arkansas, and Paragon during their first years of flower formation is associated with derangements occurring in the development of the egg nuclei. In Stayman, this abscission may be associated with chromosome irregularities in megasporogenesis which have already been noted. Nebel (35) has pointed out recently that Arkansas and Rhode Island Greening have irregularities in microsporogenesis. The writer has observed irregularities in megasporogenesis of both these varieties and also of Winesap. Paragon is almost indistinguishable from Arkansas and has similar irregularities in megasporogenesis.

At present we know of no method of preventing excessive abscission during the first flowering years when it occurs in Arkansas, Paragon, Delicious, Stayman, and others with similar characteristics. According to the assumption that the trees are over vigorous, it has been stated that trees changed from the cultivation to the sod system of culture will produce favorable effects. On the other hand, others state that the set increases with increased growth. As far as Stayman is concerned, the young trees in the Station orchards have set fruit satisfactorily by the third year of flowering. The flowers have not exhibited a tendency to abscise to an undesirable point. Stayman Winesap, during its first flowering years, sets very much better than Arkansas and Paragon. At present, experimental work on the setting of the flowers of young trees of these varieties is desirable.

EFFECT OF PRUNING UPON THE LIGHT-SETTING VARIETIES

The effect of pruning upon light-setting varieties of fruit, although generally known to be favorable, has received less emphasis than nitrogen fertilization. It is commonly assumed that pruning, by decreasing the number of flowering points, increases the food and moisture supply to those left. Moisture is also conserved by the reduction in transpiration area. In this connection, Heinicke (25) reported the favorable effect of pruning upon nitrated and non-nitrated Anjou pears which were not setting fruit. Pruning resulted in fruiting on practically all flower-bearing spurs of the heavily pruned trees in 1923, the year of pruning, while in 1925 the heavily pruned trees fruited well and the unpruned set a very light crop. He also reported the favorable effect of pruning upon 17-year-old Rhode Island Greening trees which had produced flowers for a number of years without setting fruit satisfactorily. There was a very definite response year after year to the pruning. The crop was confined to the trees with the lower limbs removed or to the limbs with many side branches removed. Oskamp (36) reported favorable effects of pruning upon another Rhode Island Greening orchard. Murneek (34) presented data from pruning one tree of each pair of several varieties, including Stayman. The differences were rather small and possibly insignificant.

RELATION OF PRUNING TO COMPETITION BETWEEN FLOWERS

Inasmuch as the defloration experiments indicated that alleviation of the competition between the flowers of a cluster increased the set of fruit, the writer attempted to determine the effect of high vigor on the set of flowers on undeflorated clusters.

From 1927 to 1930, the writer gave a rather heavy thinning-out pruning to a number of mature Stayman trees receiving 10 pounds of nitrate of soda. Other trees were pruned lightly on one side and moderately heavy on the other. Observations were made in all parts of the trees to determine the effect of the treatments upon the proportion of clusters with two or more fruits after the first abscission period. Where the stimulation was the highest a fair proportion of the clusters had from two to four fruits. (Fig. 11). These results demonstrate the fact that the competition which exists between the flowers and fruits on the cluster base is alleviated in part by practices which permit a greater water and nitrogen supply to the individuals concerned.

Whether the beneficial effect of the pruning was due to greater water or nitrogen supply or to both cannot be stated. In all likelihood both are concerned. Although there are no well defined experiments in the literature which demonstrate that pruning is more effective than nitrogen fertilization upon varieties which have a tendency to set lightly, it is probable, however, that pruning, through its additional effect upon the water supply is likely to give a more marked effect than nitrogen alone. In this connection, Heinicke (25) reported that pruning gave a more favorable response than was obtained with trees fertilized with nitrogen. He also noted increases in set from pruning before bloom for trees growing in a soil in which the amount of nitrogen was so high that the trees made no response to further application. As stated by Chandler (4), a water deficit may actually occur between the flowers and fruits of a cluster even though the supply of moisture in the soil is relatively high, for the leaves are able to draw water from the flowers and young fruits during the fruit-setting period. Thus, it is likely that pruning compensates for a partial deficit of water and increases the percentage of flowers setting fruit more appreciably than any other factor, with the possible exception of ringing.

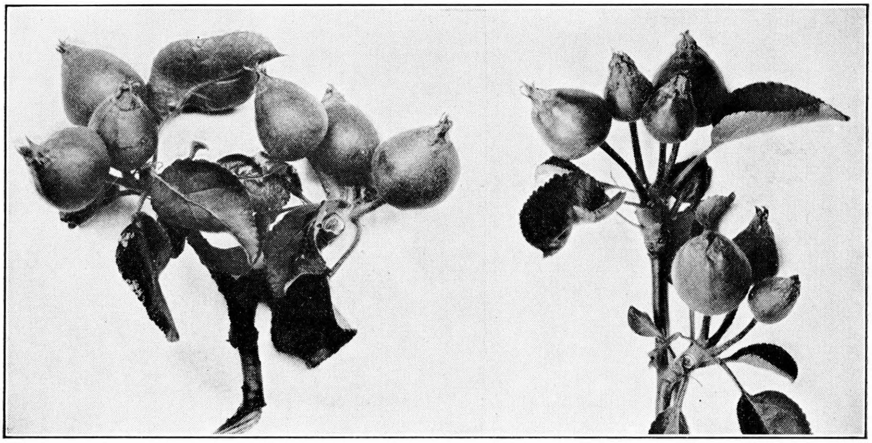

Fig. 11.—Left. Type of fruit bearing on small number of clusters in response to stimulation of high vigor in mature, bearing Stayman trees. 1928.

Right. When the first set is heavier in Stayman clusters, the second drop is somewhat heavier. The heavy first set was in response to heavy pruning and nitrogen fertilization.

Although the experimental pruning on the mature trees was rather heavy, it should be understood that the pruning in commercial plantations of the light-setting varieties should not be heavy. It should consist of a well distributed thinning out of small twigs and branches so that the invigorating effect will be present uniformly throughout the tree. Failure to prune annually such light-setting varieties as Stayman, Delicious, Arkansas, and Rhode Island Greening increases the probability that the fruits set may not be equivalent to a full commercial crop. This of course applies generally. Such results would not likely be apparent the first year, providing the tree had received adequate nitrogen fertilization.

EFFECT OF NITROGEN FERTILIZATION UPON LIGHT-SETTING VARIETIES

The favorable effect upon fruit setting of a readily available nitrogen fertilizer is generally known. On Stayman, Cullinan and Baker (10) in Indiana concluded that nitrogen increased the set of the flowers on the trees in the Stayman grass plots. In the experiments reported in this bulletin the trees of low vigor, H-2, I-3, and I-2, have never produced satisfactory yields, while tree E-5 has set full crops regularly. On the other hand, Roberts (40, 41) stated that early application of nitrate of soda does little for heavy dropping varieties, such as Winesap, since with such applications the abscission shortly after bloom was still heavy. The Stayman Winesap and Stayman trees at the Ohio Experiment Station regularly show a favorable response to nitrogen applied before bloom, even though such application does not prevent the first drop, which is comparatively heavy under any conditions. Luce and Morris (30) also presented data showing that early applications of nitrogen did reduce the severity of the drop to some extent. Heinicke (24) reported that with the variety Arkansas, early spring applications increased the set of flowers.

There is no question, however, but that fertilization with nitrogen in the case of the light-setting varieties should be early in order to insure satisfactory fruit setting. Where it is impossible to apply it early enough to insure availability to the flowers by full bloom, the nitrogen should be applied in the fall. Luce and Morris (30) obtained very favorable results from fall fertilization on Winesap. Gourley (22) has obtained very satisfactory yields on Stayman trees fertilized in the fall. These trees were companions to the trees of low vigor used in the experiments reported in this bulletin.

There is no doubt but that failure to fertilize Stayman Winesap either in the fall or early spring may be conducive to insufficient fruit setting. Nitrogen fertilization, if omitted occasionally, may not result in excessive abscission if the trees have been pruned and are in good vigor. Yet the most desirable practice is a proper combination of nitrogen fertilization and intelligent pruning.

EFFECT OF POLLINATION UPON FRUIT SETTING

The pollination experiments reported in the literature, as well as in this bulletin, show that Stayman Winesap has a very low degree of self fruitfulness. Usually no fruits were obtained from selfed flowers although occasionally a few out of a large number of flowers enclosed within cheesecloth bags would set fruit. The irregularity in sporogenesis is undoubtedly an important factor in causing this low degree of self fruitfulness. The writer has recently (28) pointed out, as a result of pollination work from 1924 to 1930, that in Stayman this degree is lower than that of the varieties Jonathan, Grimes, Wealthy, Rome, and Gallia Beauty, but similar to that of McIntosh, Arkansas, Winesap, Tompkins King, and Rhode Island Greening.

In view of the necessity of thorough cross pollination of Stayman, it seems best that no trees of Stayman be planted more than two rows (80-90 feet) from their cross-pollinizing varieties. MacDaniels and Heinicke (31) reported that during unfavorable blooming seasons McIntosh trees even two rows from their pollinizer had less than full commercial crops. Since Stayman and McIntosh have similar degrees of self-unfruitfulness, it is likely that isolation would be just as detrimental in Stayman. Furthermore, the low degree of self-fruitfulness in Stayman requires that the number of cross-pollinizing agents be particularly abundant. Insufficient bees will obviously be more detrimental in reducing the set of Stayman than in varieties such as Jonathan and Rome Beauty.

POLLINIZERS FOR STAYMAN

Various experiments have been carried out to determine the most effective pollinizing varieties for Stayman. No evidence has appeared in the literature which justifies the conclusion that one variety is more effective than another, provided the pollen is highly germinable and blooming periods are concurrent. The data presented here indicate that, of the varieties used in comparable tests, no differences in the relative effectiveness of Delicious, Gallia Beauty, Grimes, and Jonathan could be noted. This conclusion is based on the percentage of flowers setting fruit, as well as on the seed content of the fruits produced.

It is hardly justifiable to conclude from small differences in the percentage set that one variety is more effective as a pollinizer than another, provided both varieties have highly germinable pollen.

Spurs and branches may appear to be of equal growth and vigor and yet will give differences in percentage set due to variations in nutritional conditions.

In this connection, Crane and Lawrence (9) state that "the best measure of incompatibility in apples is provided by the number of viable seeds per fruit". This is possibly a reasonable conclusion in view of the correlation between seed development and fruit formation in apple varieties.

EFFECT OF FROSTS UPON FRUIT SETTING

Frosts have been the principal limiting factor on the fruit setting of Stayman in Ohio.

In the first place, this is the result of the great tenderness of Stayman flowers. Records during the blooming seasons at Wooster, as well as the observations of fruit growers, confirm this point. The variety is more tender than Jonathan, Grimes, or McIntosh; for example, in 1921 Stayman suffered more damage than these varieties when the temperature fell to 20° F. at a time when the flowers of the above mentioned varieties were in full pink. In 1922, the temperature fell to 21.5° F. when the flowers were pink with greater injury to Stayman than to Ensee, Baldwin, Stark, and Yellow Transparent. In 1930, considerably more damage was done to Stayman during the frosts on April 23 to 25 than to Jonathan and Grimes, even though these varieties were at practically the same stage of development. In this connection, Swinson and others (43) presented data indicating that during the period from 1922 to 1925 in the Shenandoah-Cumberland region, with one to three successive frosts, the commercial yield was reduced more than that of York, Ben Davis, or Yellow Newtown. With frosts four times, all were similarly reduced in yield.

A considerable amount of injury to the terminal flower is common. As pointed out in another section of this bulletin, there was considerable abortion of the pistils of terminal flowers, due probably to freezes. Under these circumstances, the lateral flowers developed normally and set sufficiently to give full commercial yields. The experiments have indicated that as high a percentage set may be obtained when the terminal flower is killed by a frost before bloom as when the terminal is uninjured. The depressing effect of the terminal upon the set of the laterals has thereby been alleviated. This emphasizes the importance of providing adequate cross pollination in Stayman plantings following a frost in order to insure the setting of uninjured flowers.

It has occasionally been noted that the killing of a considerable number of flowers may have the effect of deflorating the clusters, thus bringing about as satisfactory a yield as would be obtained otherwise. This result has been observed over a period of years and on many trees of Stayman. In 1930, on two trees located in a frost pocket, 90 to 95 per cent of the flowers were, by actual count, killed by frosts before bloom. One tree produced a half crop, a yield exactly commensurate with the 17-year average of the tree; the other tree produced a yield slightly less than the 17-year average. Other Stayman trees with 40 to 70 per cent of their flowers killed produced full commercial crops.

It had become evident, however, that frosts after bloom are much more detrimental to the commercial yield of Stayman than to the heavy setting varieties, such as Grimes and Jonathan. The reason for this greater reduction in Stayman lies in its characteristically heavy first drop. Frost injury to the one fruit on a considerable number of Stayman clusters will be more effective in reducing the yield than the same percentage of injury to the flowers of the heavier setting varieties. However, even with an after-bloom frost, Stayman may possibly produce a satisfactory yield.

Trees of Stayman high in vigor produce greater crops in years of frosts than trees low to moderate in vigor. Whether vigor increases the resistance of flowers and fruits to frost is questionable. It does, however, reduce the number of flowers and fruits abscising because of unfavorable nutritional conditions.

THE SECOND ABSCISSION PERIOD IN STAYMAN

The data presented in Figures 9 and 10 show that Stayman has a distinct second period of abscission. The amount of abscission during this period was shown to be usually light and negligible. It was comprised of fruits of varying sizes and varying numbers of seeds. Fruits which were "sets" during the early part of the period were "drops" during the latter part. Pruning and fertilization prevent an excessive late drop by supplying food and water to the partially developed fruits, thus permitting many with a small seed content to remain. Chromosomal irregularities, inadequate cross pollination, and frost and insect injury to seeds (all of which reduce the seed content) are important factors regulating the severity of the abscission during the second abscission period.

SUMMARY

The experiments in this bulletin present the factors of primary importance in the fruit setting of Stayman Winesap.

The trees used were growing in the orchards of the Ohio Agricultural Experiment Station at Wooster. The period of the experiments was from 1925 to 1931, inclusive.

The primary conclusions drawn from the various experiments are:

I. The defloration experiments have shown that one of the principal factors responsible for the severity of the first drop is the competition among the flowers on the cluster base.

1. The competition for food and water up to full bloom was not sufficiently great to prevent flowers from setting fruit, provided the clusters were partially deflorated just as the flowers were exposing the anthers. The period of competition affecting fruit setting was probably subsequent to pollination and during the few days following petal fall.

2. The competition occurs not only between the terminal flower and the lateral flowers but also among the laterals themselves.

3. When the terminal was uninjured it depressed the set of the laterals. Only on the more vigorous clusters did laterals set in competition with the terminal.

4. The greater proportion of the laterals which set in competition with the terminal were those in the axils of subtending leaves, rather than those in the axils of bracts.

5. When the terminal was absent or injured the laterals set a higher percentage than otherwise.

6. With the terminal flower eliminated from the competition, the laterals in the axils of subtending leaves still set a higher percentage than those in the axils of bracts.

7. The smallest lateral, usually the one adjacent to the terminal and the last to open, failed to set, either alone or under competitive conditions, as satisfactorily as the larger lateral in the axil of a bract.

8. These experiments indicate that the foliage leaf subtending a lateral is a factor in setting. It is not, however, of primary importance.

9. Stayman Winesap normally has two distinct periods of abscission.

10. In relation to Stayman Winesap, the set of Jonathan after the first abscission period is much greater. Three to five fruits are usually present on a large proportion of the flowering points.

11. The terminal flower in Jonathan clusters has very little depressing effect upon the laterals.

II. The pollination experiments showed that Stayman has a very low degree of self fruitfulness.

1. In the cross-pollination experiments, Gallia Beauty, Delicious, Starking, Golden Delicious, Grimes Golden, and Jonathan were effective pollinizers.

2. No difference in the relative effectiveness of Grimes Golden, Delicious, Gallia Beauty, and Jonathan as pollinizers for Stayman were observed when measured by (a) percentage of flowers setting fruit and (b) number of well-filled seeds per fruit.

III. The microscopical studies of Stayman Winesap have shown that an important factor in the fruit setting of this variety is irregularity in chromosome behavior at megasporogenesis.

1. These irregularities working in conjunction with the competition between flowers are responsible for the heavy first drop in Stayman Winesap.

2. They are responsible in part for the low degree of self fruitfulness of the variety.

3. In Jonathan, irregularities in megasporogenesis are scarce.

4. The experiments indicate that the maintenance of a high level of nutrition compensates in part for these irregularities in chromosome behavior at megasporogenesis and allows the production of full commercial crops, provided the flowers are effectively cross pollinated.

PRACTICAL CONSIDERATIONS FOR THE GROWER

The study presented in the foregoing pages is concerned with a determination and analysis of the factors responsible for the rather capricious fruit-setting habit of Stayman Winesap.

Two factors working in conjunction are responsible for the heavy drop of flowers shortly after bloom: competition between the flowers of a cluster for food and water, and irregularities in the processes leading to the development of the egg nuclei. On trees of weak to moderately weak growth the competition between flowers is so severe that many fail to set even though cross pollinated. In order to compensate for and alleviate the effect of the irregularities, the trees should be stimulated to make a vigorous growth.

PROPER GROWTH CONDITIONS

In connection with the establishment and maintenance of proper growth conditions for fruit setting in Stayman Winesap certain suggestions are advanced in relation to pruning and nitrogen fertilization.

Pruning.—Although an occasional failure to prune Stayman annually may have no immediately unfavorable effect, pruning should be *regularly* carried out during the dormant period or up to a few days before full bloom.

The pruning, consisting of small rather than large cuts, should invigorate as large an area of the tree as possible. Trees bearing satisfactory crops and pruned regularly require only a light thinning out.

Nitrogen fertilization.—The application of readily available nitrogen fertilizer should be made not later than *2* weeks before bloom. Although the application may be delayed on varieties such as Jonathan and Grimes, a delayed application on Stayman may result in an excessive first drop. Fall applications have also produced satisfactory results on fruit setting in Stayman.

PRESENCE OF EFFECTIVE CROSS-POLLINIZING VARIETIES

The experiments presented in this bulletin, as well as those from other states, show that Stayman will produce few or no fruits when self pollinated. The degree of self fruitfulness of the variety is extremely low, being less than Jonathan, Rome, Wealthy, and Baldwin.

The following varieties are effective as cross pollinizers of Stayman Winesap:

Ben Davis	McIntosh
Cortland	Oldenburg
Delicious	Red Rome Beauty
Gallia Beauty	Rome Beauty
Gano	Starking
Golden Delicious	Wealthy
Grimes Golden	Winter Banana
Jonathan	Yellow Transparent
King David	York Imperial

Experiments carried out at Wooster indicate that Delicious, Gallia Beauty, Grimes Golden, and Jonathan are of equal value as pollinizers of Stayman. Gallia Beauty, however, should not be planted as the only pollinizer of Stayman because of its late blooming habit.

The following varieties are of no value as pollinizers for Stayman since they have pollen of very low germinability:

Arkansas (Black Twig)	Paragon
Baldwin	Rhode Island Greening
Gravenstein	Tompkins King
Ohio Nonpareil	Winesap

Varieties to be valuable as pollinizers for Stayman should possess the following qualifications:

1. Highly germinable pollen.
2. Sufficiently overlapping season of bloom.
3. Desirable commercial variety.
4. Annual bloom, or sufficient flowering for source of pollen.
5. Age of first flowering contemporary to Stayman.

Highly germinable pollen.—In addition to the effective pollinizers listed above, all other varieties whose pollen is highly germinable are effective on Stayman.

Sufficiently overlapping season of bloom.—Recently, Ellenwood has presented in Ohio Agricultural Experiment Station Bulletin 472 the summary of the blooming season records at Wooster for the last 20 years. It shows that, with the exception of Rome Beauty, Northern Spy, Gallia Beauty, Mother, and Ralls, the blooming seasons of all varieties overlap that of Stayman sufficiently to be effective as the only pollinizer of that variety. The variety which is to be the pollinizer of Rome should be planted so as to supplement Rome as the pollinizer of Stayman. Gallia Beauty and Red Rome have the same blooming periods as Rome and would be subject to the same limitations.

Desirable commercial variety.—Sufficient varieties of commercial importance are available so that there is no necessity for selecting a variety commercially unimportant.

Annual bloom or sufficient flowering for source of pollen.—It is obvious that a variety planted as a pollinizer of Stayman should have at least some flowers each year. The most decided alternate bearers at Wooster have been Oldenburg and Yellow Transparent.

Age of flowering contemporary to Stayman.—Ellenwood, in Bulletin 472, has presented the varieties which come into bearing at approximately the same age as Stayman.

DISTANCE OF STAYMAN TREES FROM THEIR POLLINIZING VARIETY

No Stayman trees should be more than 2 rows (80 feet) from their pollinizers (Fig. 12). In blooming seasons unfavorable for bee flight it is likely that Stayman trees in the third row from their pollinizer will be inadequately pollinated, even with bees present. Four rows of Stayman may be planted together if effective pollinizers are adjacent on each side. (Fig. 13). It should also be kept in mind that the variety intended as the pollinizer of Stayman should not be isolated at the edge of the planting without provisions being made for its pollination as well.

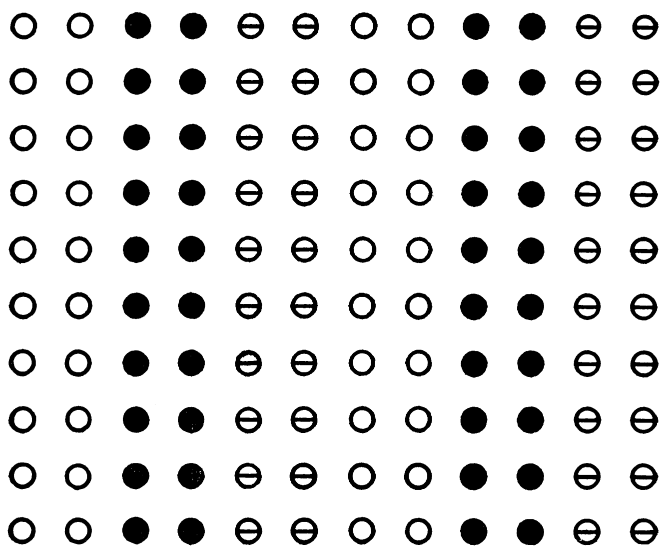

Fig. 12.—Planting plan when Stayman Winesap, indicated by circle, is started at the border of a planting. There should be only two rows of Stayman followed by its pollinizer (in this plan, Jonathan, indicated by solid circle), followed by the pollinizer of Jonathan (in this case, Delicious, indicated by bisected circle).

We may add that there is no justification for mixing varieties within the Stayman rows other than as fillers.

Plantings established but not yet bearing flowers.—When provision was not made for cross pollination at the time of planting, effective, cross-pollinizing varieties must be added. If the trees are 4 years old, top working will provide a source of pollen within the shortest time.

It is suggested that every third row of Stayman be topworked (Fig. 14). The trees in this pollinizing row must consist of at least two varieties capable of cross pollinizing each other. The trees of the two varieties need not be equally divided, however.

In an orchard planted to Stayman and another variety with poor pollen, the planting must be topworked as if it were a solid block of Stayman.

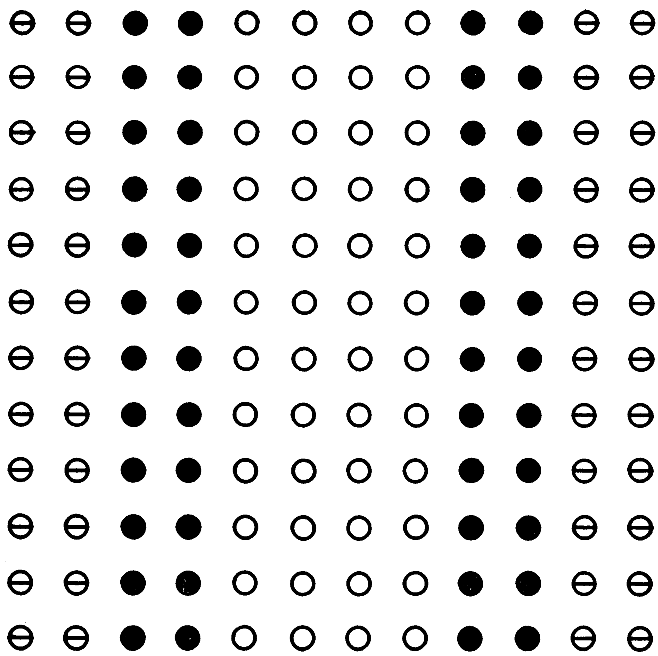

Fig. 13.—In this planting plan no tree of either Stayman Winesap, indicated by circle, Jonathan, indicated by solid circle, or Delicious, indicated by bisected circle, is more than two tree rows (80 feet) from its pollinizer. Four rows of Stayman may be planted together if pollinizers are on each side.

Trees bearing flowers.—Top working as was recommended with non-flowering trees is necessary for adequate cross pollination of solid blocks of flowering Stayman trees.

For adequate pollination during the current season and until the scions bear flowers, branches with flowers of effective pollinizing varieties must be introduced.

The pruning of effective pollinizing varieties should be delayed in order that sufficient flowering branches may be available. Flowers from fence-row seedlings may also be used.

Branches one to 3 inches in diameter are not too large. They can be placed in any available water carrier. It has been found practicable to place the containers at the outer edge of a tree so that the branches of the pollinizer may be supported among the branches of the tree to be pollinized. The containers may also be placed within the trees or in the open space between four trees. In very unfavorable blooming seasons bloom placed between four trees will likely not be as effective as that placed in the tree that is to be pollinized.

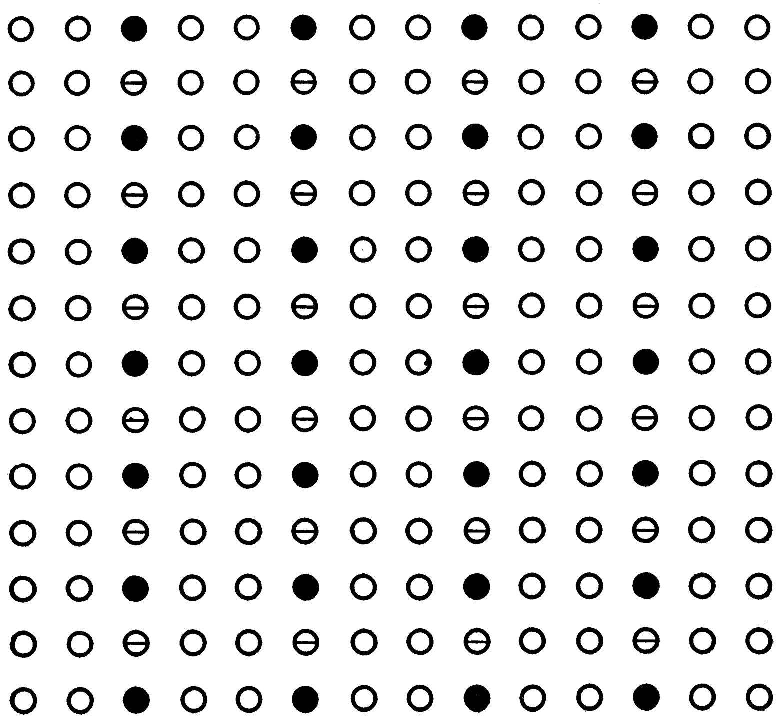

Fig. 14.—Plan suggested for topworking a solid block of Stayman Winesap, indicated by circle. Every third row is topworked to two varieties. Half of the trees in this pollinizing row are Delicious, indicated by bisected circle, and half Jonathan, indicated by solid circle.

In placing the flower containers in the planting, the habits of bee flight should be kept in mind. Individual bees will collect pollen and nectar from a localized area and will make trips to and from this area to the hive. The branches should not be placed directly in front of the hive with the expectation that the bees will fly to the flowers in the containers and off to a Stayman tree.

The flowering branches should be brought into the Stayman block as soon as the flowers begin to open and should be renewed, if necessary, until the petals on the Stayman trees fall. Some flowers on the introduced branches should be unopened so that a succession of bloom will be available, without constant changing of the branches. Usually there are sufficient flowers on limbs one to two inches in diameter to provide pollen for several days, if weather conditions are favorable.

PRESENCE OF EFFECTIVE POLLINIZING AGENTS

When Stayman trees are from 6 to 12 years old one strong hive of bees for every 2 acres should be sufficient. With trees over 12 years, one hive to every acre is none too many in an unfavorable blooming season.

FROST AS A FACTOR IN THE FRUIT SETTING OF STAYMAN WINESAP

The killing of 80 to 90 per cent of the flowers before bloom may not result in a decrease in the commercial yield per tree, since as many fruits may result as if no frost had occurred.

A frost after bloom will usually have a more serious effect on commercial yields of Stayman than of Jonathan. This is due to the fact that Jonathan usually has two to three fruits to a cluster while Stayman has a large number of clusters with only one fruit, and only a fair proportion with two fruits.

The late-opening flower clusters on the shoot growth of the previous year may, in years of heavy frosts, produce an appreciable proportion of the fruits. In years of heavy bloom and no frosts, such flowers will usually fall without setting. Provision in years of frosts should be made for thorough cross pollination during the entire period of bloom.

The fruit grower can indirectly aid in minimizing the effects of frosts by maintaining the trees in high vigor. In this way, dropping of the flowers and partially developed young fruits because of insufficient food and water supply is considerably reduced.

Site of planting.—In view of the susceptibility of Stayman flowers to frosts and the fruit setting habit of the variety, new plantings should be located only on the most frost-free sites. The importance of this cannot be overemphasized.

LITERATURE CITED

1. Auchter, E. C. 1922. Apple pollen and pollination studies in Maryland. Proc. Amer. Soc. Hort. Sci. 18 (1921): 51-80.
2. Ballard, W. R. 1916. Methods and problems in pear and apple breeding. Md. Agr. Exp. Sta. Bull. 196: 79-92.
3. Bijhouwer, J. 1923. De periodiciteit van de knopontwikkeling bij den appel (Periodicity of the bud development in the apple) Meded, v. d. Landbouwhoogeschool Dl, XXVII, en uitg. Lab. v. Plantenphys. Onderz. No. 7: 1-63.
4. Chandler, W. H. 1925. Fruit Growing. Houghton-Mifflin Co.
5. Close, C. P. 1907. Report of the Horticulturist. Apple Breeding. 16th, 17th, 18th Ann. Rept. Del. Agr. Exp. Sta. 1904-06: 42-44.
6. Cooper, J. R. 1927. Report of the Horticulturist. Pollination of Apples. Ark. Agr. Exp. Sta. Bull. 221: 15-17.
7. Crandall, C. S. 1922. Results from self-pollination of apple flowers. Proc. Amer. Soc. Hort. Sci. 18 (1921): 95-100.
8. Crane, M. B. and W. J. C. Lawrence. 1929. Genetical and cytological aspects of incompatibility and sterility in cultivated fruits. Jour. Pom. and Hort. Sci. 7:276-301.
9. ————. 1930. Fertility and vigor of apples in relation to chromosome number. Jour. of Gen. 22 (2): 153-164.
10. Cullinan, F. P. and C. E. Baker. 1927. Orchard soil management studies. Purdue Univ. Agr. Exp. Sta. Bull. 315: 1-40.
11. Detjen, L. R. 1929. The effects of nitrogen on the set of apple flowers situated variously on the cluster base. Proc. Amer. Soc. Hort. Sci. 25 (1928): 153-157.
12. Detjen, L. R. and C. F. Gray. 1928. Physiological dropping of fruits II. In regard to genetic relationships of plants. Del. Agr. Exp. Sta. Tech. Bull. 9: 1-37.
13. Dickson, Geo. H. 1929. Variability of vigor in apple seedlings. Proc. Amer. Soc. Hort. Sci. 25 (1928): 165-168.
14. Dorsey, M. B. 1922. The set of fruit in apple crosses. Proc. Amer. Soc. Hort. Sci. 18 (1921): 82-94.
15. Einset, Olav. 1930. Cross-unfruitfulness in the apple. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bull. 159: 1-24.
16. Ellenwood, C. W. 1931. Bloom period and yield of apples—a 20-year average. Ohio Agr. Exp. Sta. Bull. 472: 1-21.
17. Ewert, R. 1906. Blütenbiologie und Tragbarkeit unserer Die Obstbäume Landw. Jahr., 35: 259-287.
18. ————. 1907. Die Parthenocarpie oder Jungfernfrüchtigkeit der Obstbäume. P. 1-58. Paul Parey, Berlin.
19. ————. 1909. Neuere Untersuchungen über Parthenokarpie bei Obstbäumen and einigen anderen fruchttragenden Gewächsen. Land. Jahrb. 38: 767-839.
20. ————. 1929. Blühen und fruchten der insektenblütigen garten- und feldfrüchte unter dem einfluss der bienenzucht. Neudamm, J. Neumann.
21. Fletcher, S. W. 1900. Pollination in orchards. Cornell Agr. Exp. Sta. Bull. 181: 335-364.
22. Gourley, J. H. Results with fall fertilization of apples. (unpublished).
23. Heinicke, A. J. 1917. Factors influencing the abscission of flowers and partially developed fruits of the apple. Cornell Univ. Agr. Exp. Sta. Bull. 393: 41-114.
24. ————. 1924. The set of apples as affected by some treatments given shortly before and after the flowers open. Proc. Amer. Soc. Hort. Sci. 20 (1923): 19-25.

25. ————. 1927. The set of fruit as influenced by pruning at different periods preceding the bloom. Proc. Amer. Soc. Hort. Sci. 23 (1926): 46-48.

26. Howlett, F. S. 1926. The nitrogen and carbohydrate composition of the developing flowers and young fruits of the apple. Cornell Univ. Agr. Exp. Sta. Mem. 99: 1-79.

27. ————. 1927. Apple pollination studies in Ohio. Ohio Agr. Exp. Sta. Bull. 404: 1-84.

28. ————. 1930. Further experiments on the relative self-fruitfulness of apple varieties. Proc. Amer. Soc. Hort. Sci. 26 (1929): 49-55.

29. Knowlton, H. E. 1928. Studies in apple sterility. Proc. Amer. Soc. Hort. Sci. 24 (1927): 111-114.

30. Luce, W. A. and O. M. Morris. 1928. Pollination of deciduous fruits. Wash. Agr. Exp. Sta. Bull. 223: 1-22.

31. MacDaniels, L. H. and A. J. Heinicke. 1930. Pollination and other factors affecting the set of fruit, with special reference to the apple. Cornell Univ. Agr. Exp. Sta. Bull. 407: 1-46.

32. Maney, T. J. 1930. Growth behavior of apple seedlings grown from nursery stock. Proc. Amer. Soc. Hort. Sci. 26 (1929): 86-90.

33. Morris, O. M. 1921. Studies in apple pollination. Wash. Agr. Exp. Sta. Bull. 163: 1-32.

34. Murneek, A. E. 1930. Apple pollination investigations. Mo. Agr. Exp. Sta. Res. Bull. 138: 1-36.

35. Nebel, B. R. 1931. Recent findings in cytology of fruits. Proc. Amer. Soc. Hort. Sci. 27 (1930): 406-410.

36. Oskamp, J. 1927. Field observations in pollination in 1926. Proc. Amer. Soc. Hort. Sci. 23 (1926): 48-51.

37. Osterwalder, A. 1907. Untersuchungen über das Abwerfen junger Kernobstfrüchte. Landw. Jahrb. Schweiz 21: 215-225.

38. ————. 1909. Ueber das Abwerfen der Blüten unserer Kernobstbäume. Landw. Jahrb. Schweiz 23: 339-350.

39. Powell, G. H. 1901. Report of the Horticulturist. The pollination of apples. 12th Ann. Rept. Del. Agr. Exp. Sta. 1900: 134-139.

40. Roberts, R. H. 1924. Relation of growth and fruiting to orchard practice. Trans. I. Hort. Soc. 58: 137-142.

41. ————. 1926. Apple Physiology. Wis. Agr. Exp. Sta. Res. Bull. 68: 1-72.

42. Sax, K. 1921. Studies in orchard management, II. Factors influencing fruit development of the apple. Me. Agr. Exp. Sta. Bull. 298: 53-84.

43. Swinson, C. R., F. P. Weaver, A. J. Dadisman, J. J. Vernon, H. P. Gould, and J. B. Kincer. 1927. Factors influencing the yield of apples in the Cumberland-Shenandoah Region of Pennsylvania, Virginia, and West Virginia. U. S. Dept. Agr. Tech. Bull. 54: 1-25.

44. Taylor, W. A. 1903. Promising new fruits. U. S. Dept. Agr. Yearbook 1902: 469-472.

45. Vincent, C. C. 1920. Results of pollination studies at Idaho University. Better Fruit 14: 11-15.

46. Vinson, C. G. 1923. The pollination of apple trees. 42d Ann. Rept. Ohio Agr. Exp. Sta. Bull. 373: 43-44.

47. Wallis, E. 1911. Sterility in fruit trees. Jour. Dept. Agric. Victoria 9: 10-19.